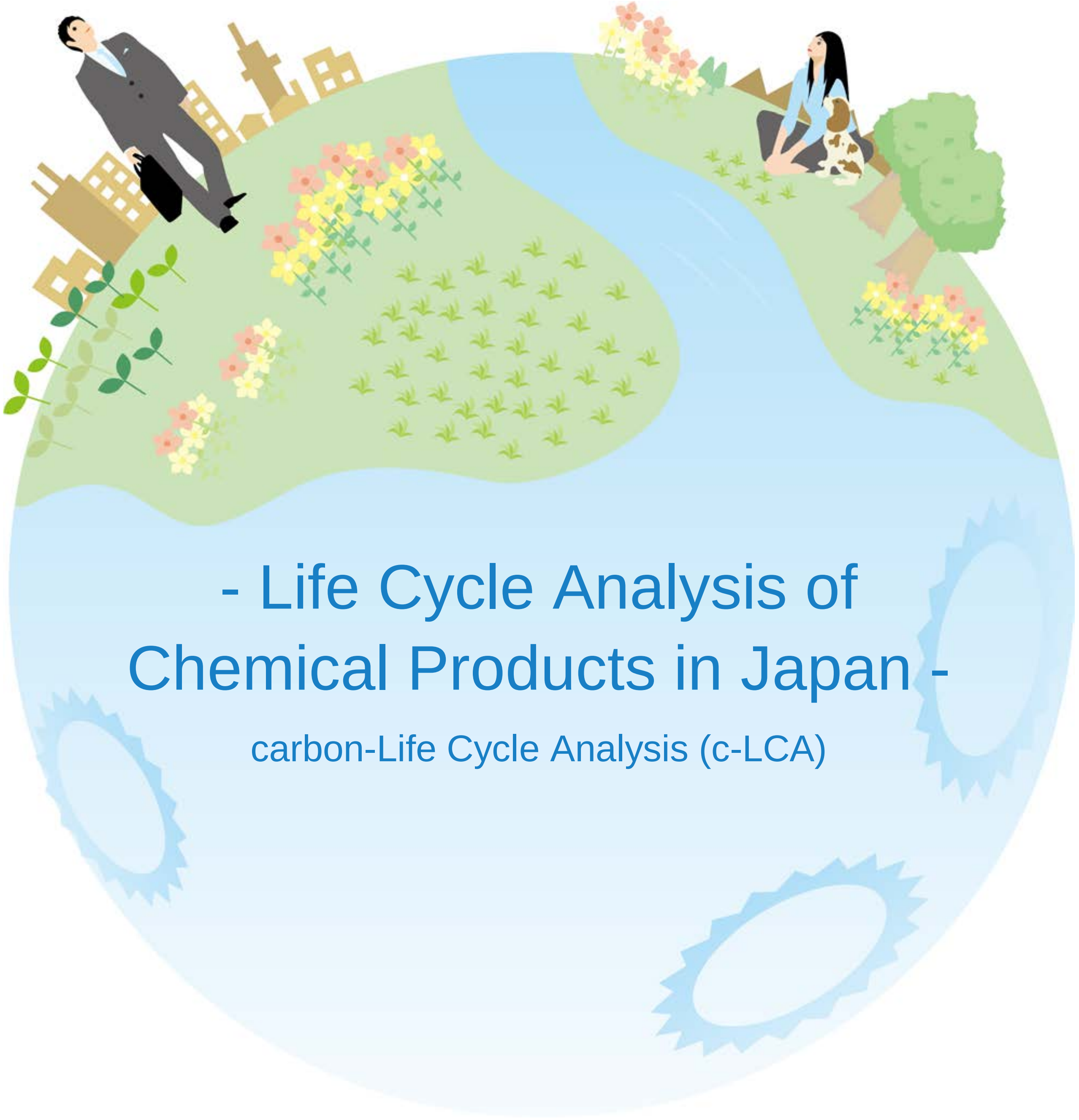
Innovations for Greenhouse Gas Reductions



- Life Cycle Analysis of Chemical Products in Japan -

carbon-Life Cycle Analysis (c-LCA)

July 2011
Japan Chemical Industry Association

Innovations in Greenhouse Gas Reductions

- Life Cycle Analysis of Chemical Products in Japan -

carbon-Life Cycle Analysis（c-LCA）

A Case Study Calculated Using Specific Conditions

July, 2011

Japan Chemical Industry Association

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Introduction

The International Council of Chemical Associations (ICCA), an organization representing chemical industry associations around the world, issued a booklet in 2009, entitled "Innovations for Greenhouse Gas Reductions, A life cycle quantification of carbon abatement solutions enabled by the chemical industry." The booklet was produced with the cooperation of McKinsey & Company and the Öko-Institut. In the booklet, logical and empirical analyses called the carbon-Life Cycle Analyses are presented, in which CO_2 emission produced in the manufacture of chemical products are compared with the reduction in CO_2 emission that results from the use of the manufactured chemical products. In this way, the booklet illustrates that the chemical industry makes a great contribution to the reduction of CO_2 emission worldwide.

That is to say, the chemical industry plays the following contribution and role in helping to solve the problem of global warming.

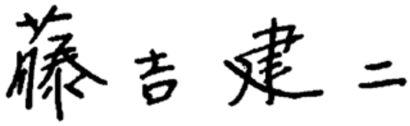
- The chemical industry has been controlling its CO_2 emission through improved energy efficiency, fuel switching, etc. despite an increase in the production volume.
- The chemical industry makes a very significant contribution to reducing CO_2 emission in other industries and people's lives through the products it provides to them.
- The chemical industry is a "solution provider", that is, the source of a resolution that provides the products and technologies required for the preventive measures against global warming.

The Japan Chemical Industry Association has recently measured the reduction in CO_2 emission that results from specific uses of chemical products in Japan, and has summarized the degree to which the chemical industry contributes to the reduction in CO_2 emission in nine fields. They include renewable energy, improvement in fuel economy through weight reduction, and energy conservation. It is our hope that this report will provide an understanding that the chemical industry is a "solution provider" that contributes to society through the reduction in CO_2 emission and also that it is important, as a preventive measure against global warming, to strive for a real reduction in CO_2 emission by understanding the state of CO_2 emission through a product's life cycle. We expect that this report will be of help when devising policies incorporating the concept of life cycle analysis and when developing technologies and materials for chemical products that will help to reduce CO_2 emission.

Last but not least, our thanks go to Mizuho Information & Research Institute, Inc., Industrial Information Research Center, K.K. and members of the Review Committee who have provided guidance and support in issuing this report.

July 2011

Kenji Fujiyoshi, Chairperson
Japan Chemical Industry Association



Executive summary

1. Overview and conclusion

The chemical industry (including plastics and rubber, but excluding metal, glass and cement[1]) helps to reduce CO_2 emission in other industries and society as a whole through the use of products. From this point of view, the International Council of Chemical Associations (ICCA) prepared its c-LCA[2] report, investigating the CO_2 emission from chemical products from the perspective of a bird's eye view of the entire life cycle, from extraction, through manufacture and use, to disposal.

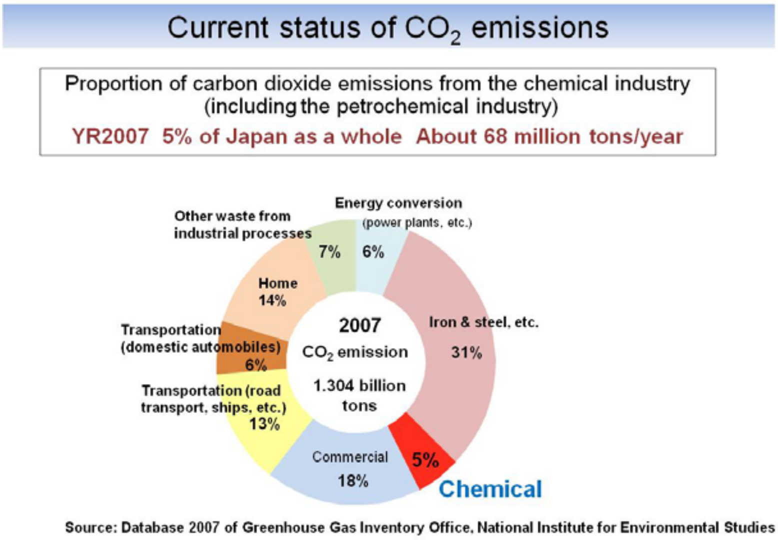
This report, using the year 2020 as the year of analysis, evaluates the CO_2 emission abatement when the products manufactured during the year of analysis were used until their end of life. Nine products that significantly reduce CO_2 emission were analyzed, for which data is available in Japan. These were in the fields of renewable energy, improved fuel economy through weight reduction, and energy conservation. Through this analysis, the avoided CO_2 emission in society at large that results from the use of specific chemical products in Japan was quantified. Note that, instead of making a comparison between the current products and the products expected to be in widespread use in 2020, a comparison was made with products that will have to be used when no chemical products are available.

These analyses showed that, while the CO_2 emission of chemical products were about 4.75 million tons during the life cycle from extraction through manufacture to disposal, these products are key materials that contribute to a reduction of about 110 million tons as finished products. Note that the avoided CO_2 emission includes of the contribution of chemical products as well as that of other products related to raw materials and material-related products. However, since no means are currently available to quantify the contribution of other products, the degree to which each constituent product helps to reduce CO_2 emission is not determined.

These results suggest that, to promote reduced CO_2 emission, which is a global problem, it is important that measures be taken from the perspective of pursuing total optimization through a full understanding of the life cycle of products, instead of considering partial optimization, such as that for the reducing CO_2 emission during manufacture. From this point, the chemical industry is committed to helping to reduce CO_2 emission in society as a whole by using chemical technologies and products throughout the entire life cycle, without simply striving to reduce emissions only during manufacture.

2. The chemical industry in Japan

The chemical industry is a high energy-consuming industry that uses fossil resources, mainly petroleum, as fuels and raw materials. However, the chemical industry in Japan took active measures to conserve energy after the oil shock and achieved the highest level of energy efficiency in the world. Consequently, CO_2 emission from energy sources during the manufacture of chemical products in Japan were about 68 million tons in 2007, accounting for about 5% of the emissions of Japan as a whole (about 1.3 billion tons).



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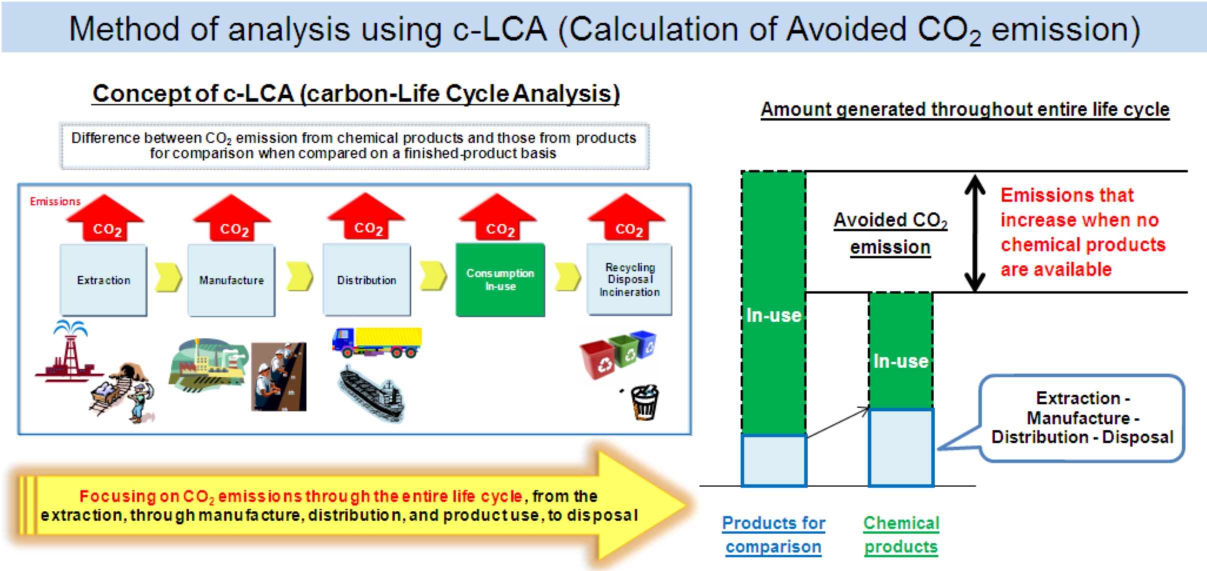
[1] Reference: Website of the Ministry of Economy, Trade and Industry "Statistical Investigation of Industries, Material Related to Classification, Industrial Classification Code File" http://www.meti.go.jp/statistics/tyo/kougyo/result-4.html#menu08 In the Subsector of Industrial Classification (2 digits), 16, 18 and 19 are being considered.

[2] Carbon-Life Cycle Analysis

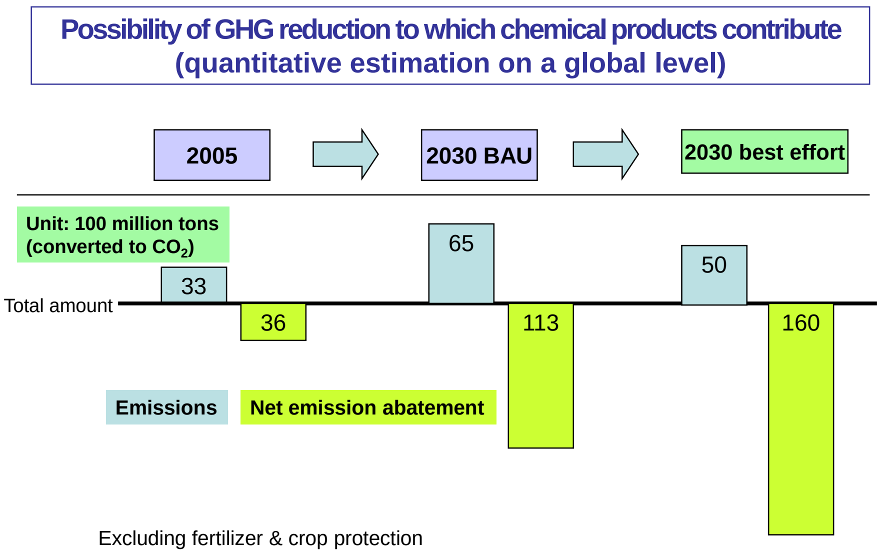
3. The concept of c-LCA (from the ICCA report)

The chemical industry is a basic industry that supports other industries by providing its products to user enterprises in sectors that include automotive, electric machinery and electronics. The method of analysis using c-LCA focuses on GHGs[3] that are emitted when used in other industries. It quantifies the emissions of finished products using chemical products over their whole life cycle in comparison to the emissions of finished products using products for comparison, and it calculates the differences as the avoided CO_2 emission by considering the differences as emissions that increase when assuming that the chemical products are not available.



According to the ICCA report, the global avoided emission in 2030 on a best-effort basis is estimated to be ▲16 billion tons in total, excluding GHG emissions from agricultural materials.

Global anthropogenic GHG emissions in 2005 are estimated to be around 46 billion tons (WEF 2007[4]), with 16 billion tons in emissions reductions translating into a contribution to reductions equivalent to about one-third of the total emissions.



Excluding fertilizer & crop protection

Source: Innovations for Greenhouse Gas Reductions By ICCA
ICCA : International Council of Chemical Associations

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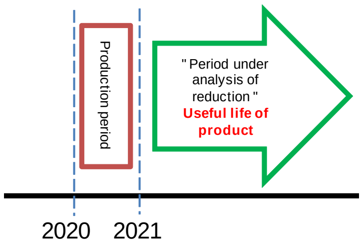
3 Greenhouse Gases: 6 types, i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O)(= dinitrogen monoxide), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

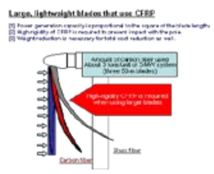
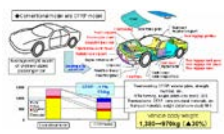
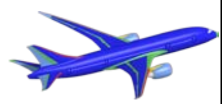
4 World Economic Forum 2007 (commonly known as Davos Forum)

4. Summary of the examples of analysis in Japan in 2020

[Period under analysis]
With 2020 used as the year of analysis, the avoided CO_2 emission was evaluated when the products manufactured during the year under analysis were used until the end of their life.

[Range of the products under analysis contributing to avoided CO_2 emission]
Chemical products help to reduce CO_2 emission in finished products in various fields, such as the energy sector, transportation sector and the home and consumer sector in cooperation with other products related to raw materials and material-related products.

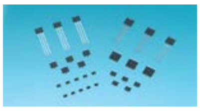


	Renewable energy		Improvement in fuel economy by weight reduction	
	Solar power	Wind energy	Automotive	Aircraft
Concept				
Functions	Solar energy is converted directly into electricity through the application of the principle of semiconductors.	The generator is turned directly by the force of the wind. Larger systems can be achieved by increasing rigidity through the use of carbon fiber.	Using carbon fiber, weight reduction is achieved while maintaining performance and safety.	Same as at left
Products under analysis (finished products using chemical products)	Multicrystalline Silicon solar cells	Wind turbine using plastics reinforced with carbon fiber	Carbon fiber reinforced plastics	Carbon fiber reinforced plastics
Products for comparison (finished products using products for comparison)	Electric power utilities	Electric power utilities	Steel	Aluminum alloy
Contents of the effect of reduction	No CO_2 is emitted because fossil fuels are not used.	Same as at left	Weight reduction improves fuel economy and reduces fuel consumption.	Same as at left
Extraction - manufacture - disposal emissions (k tons)	1,290	9	93	176
Range*1	**Extract - manufacture**	**Extracts - manufacture**	**Extract - manufacture/ assembly - disposal**	**Extracts - manufacture/ assembly**
Avoided CO_2 emission (k tons)	▲8,980	▲8,540	▲75	▲1,220
Total (excl. seawater desalination)	**Avoided CO_2 emission in Japan:**			

*1: **Blue letters** show the effective data range of chemical products only. **Green letters** shows the effective data range of finished products that use chemical products.

[The effect of helping to reduce emissions]
Based on the total value in the eight examples used here, it can be seen that chemical products are a key material that helps to reduce emissions totaling 112 million tons until their end of their life. However, there remains a problem in the products for comparison concerning thermal insulation materials for housing, which play a major role in reducing CO_2 emission. The problem of improving the method of calculation needs to be addressed hereafter.

[Degree of contribution to reduced CO_2 emission]
Since the CO_2 emission of the finished products that use chemical products to help reduce CO_2 emission are around 4.75 million tons, it can be seen that the degree to which chemical products help to reduce CO_2 emission far exceeds the emissions of the chemical products themselves.

Energy saving				
LEDs	Thermal insulation for housing	Hall effect device	Piping materials[*2]	Seawater desalination[*3]
				
A semiconductor that emits light when current flows. Light-emitting efficiency is high and the useful life is long.	Increases the air-tightness and thermal insulation of housing.	Commutatorless motor. Use of the device to detect rotor position increases the efficiency of motive power.	Has the same performance as that of pipes made of cast iron, and is widely used in waterworks and sewage.	Using a semi-permeable membrane, desalinates seawater based on the principle of reverse osmosis.
LED light bulb	Foamed thermal insulation material Polyurethane Polystyrene	DC brushless motor (for air conditioning)	PVC pipe	Desalination membrane made of RO membrane
Incandescent light bulb	Non thermally-insulated housing	AC motor (for air conditioning)	Ductile cast iron pipe	Evaporation method
Long useful life and low power consumption.	Reduces power consumption for cooling and heating.	Reduces power consumption by increasing efficiency.	Low energy consumption because high temperatures are not used during manufacture.	Low energy consumption because no heating is required.
92	2,350	<<1	740	1,500
Extract - manufacture/assembly - disposal	**Extract - manufacture - disposal**	**Extract - manufacture**	**Extract - manufacture/processing - disposal**	**Extract - manufacture/ construction - disposal**
▲7,450	▲76,000	▲6,400	▲3,300	▲170,000 (Effect throughout the world)
▲112 million tons				

*2: Emissions from extraction through manufacture and disposal are compared instead of in-use emissions.
*3: Mainly used in propagation overseas.

1. About the chemical industry

1.1 Features of the chemical industry

The chemical industry plays an important role by providing other industries, such as automotive, electric machinery/electronics, pharmaceuticals and cosmetics, with raw and other materials for processing.

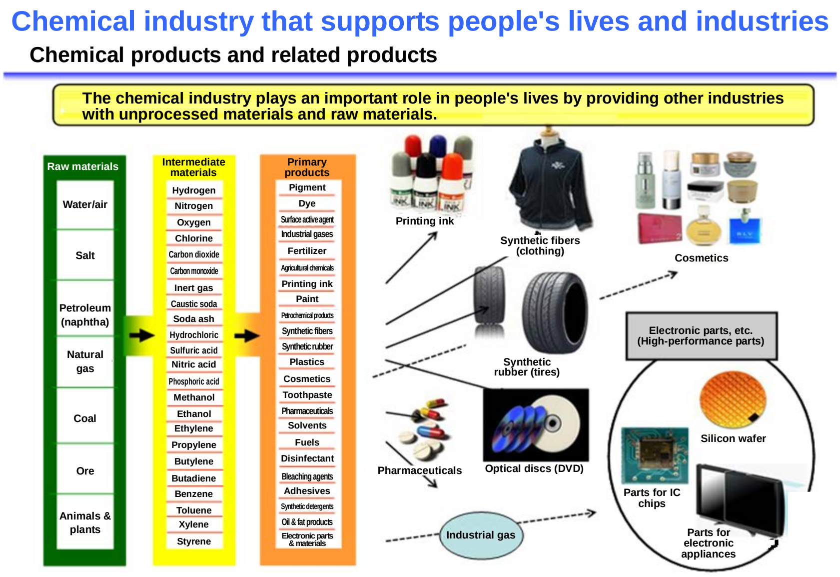


Fig. 1. The chemical industry that supports daily living and industries

1.2 Features of the chemical industry in Japan (overview as of 2008)

[1] Ranked the second of Japan’s manufacturing industries in added value

[2] Employs 930,000 people

[3] A basic industry that supports the competitiveness of industries in Japan through the supply of high-grade material-related products to enterprises in sectors such as the automotive and electric machinery/electronics industries

[4] A high energy-consuming industry that uses fossil resources as raw materials and fuels

[5] An industry subjected to international competition with Europe, America, Asia, etc.

	Volume shipped	Added value	Number of employees	Added value per capita
	Trillion yen	Trillion yen	10,000 persons	10,000 yen
Total for manufacturing industries	335.6	101.3	836.5	1,211
Entire chemical industry (Ratio to total for manufacturing industries)	43.7 (13%)	15.4 (15%)	92.9 (11%)	1,660
Entire electric/information/electronics	51.9	15.1	127.2	1,190
Transportation machinery & equipment manufacturing industry	63.8	15.7	103.0	1,520
General machinery & equipment manufacturing industry	40.2	14.8	121.9	1,214

Source: "Industrial Statistics Tables" from the Ministry of Economy, Trade and Industry; "Investigative Research on Science and Technology" from the Ministry of Internal Affairs and Communications; "Statistics on Corporate Financial Statements by Industry" from the Ministry of Finance

Table 1. Amount shipped, added value and number of employees of each industry

1.3 Approach taken by the chemical industry in Japan to the prevention of global warming

(1) Present situation of CO_2 emission

Proportion of CO_2 emission in each sector

Industrial CO_2 emission account for 36% of Japan's total emissions, with the remaining 64% being emitted by commercial, transportation and household sources. The chemical industry's position in the industrial sector is second after the steel industry, and its emissions account for 5% of Japan's total emissions.

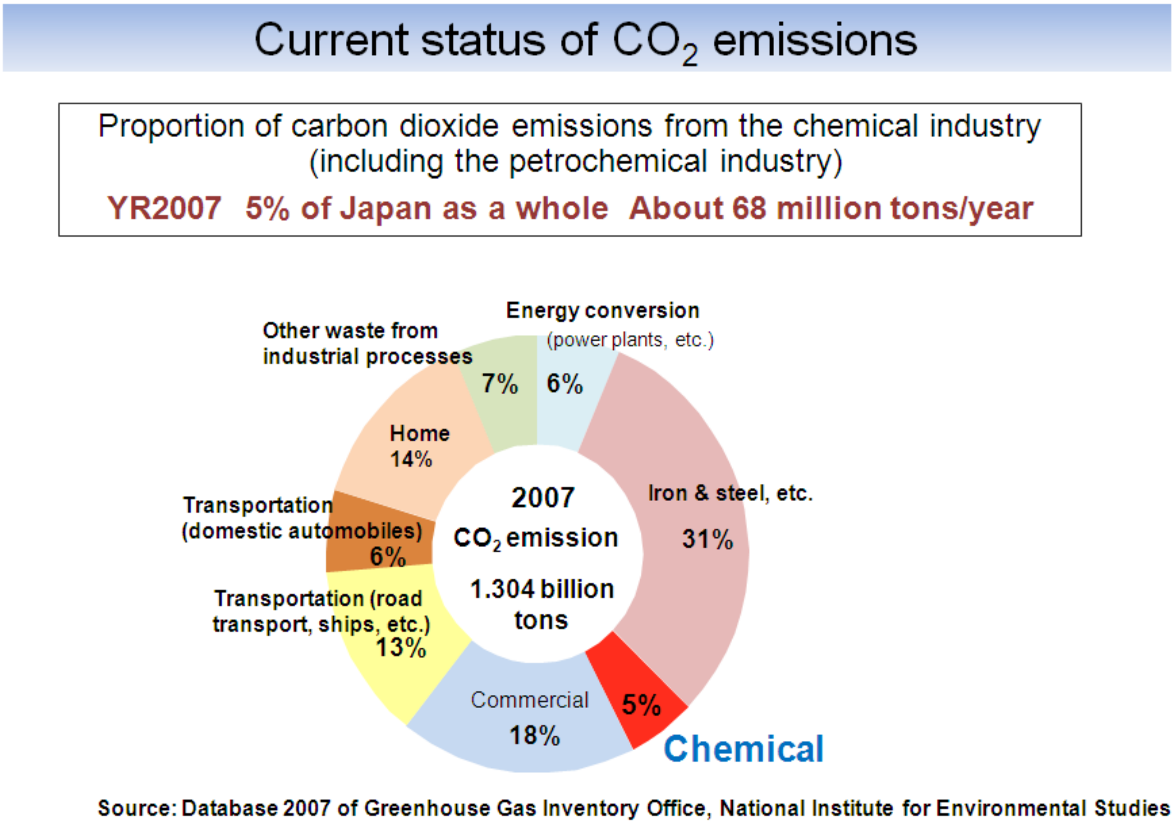


Fig. 2 Proportion of CO_2 emission of the chemical industry

(2) Approach taken by the chemical industry in Japan to energy conservation initiatives

Change in the amount of energy used in each sector

The energy consumption of the industrial sector to which the chemical industry belongs remains flat. However, in recent years, energy consumption in the commercial and the household sectors has been increasing, and it has become a problem to be addressed as Japan overall strives to reduce its CO_2 emission.

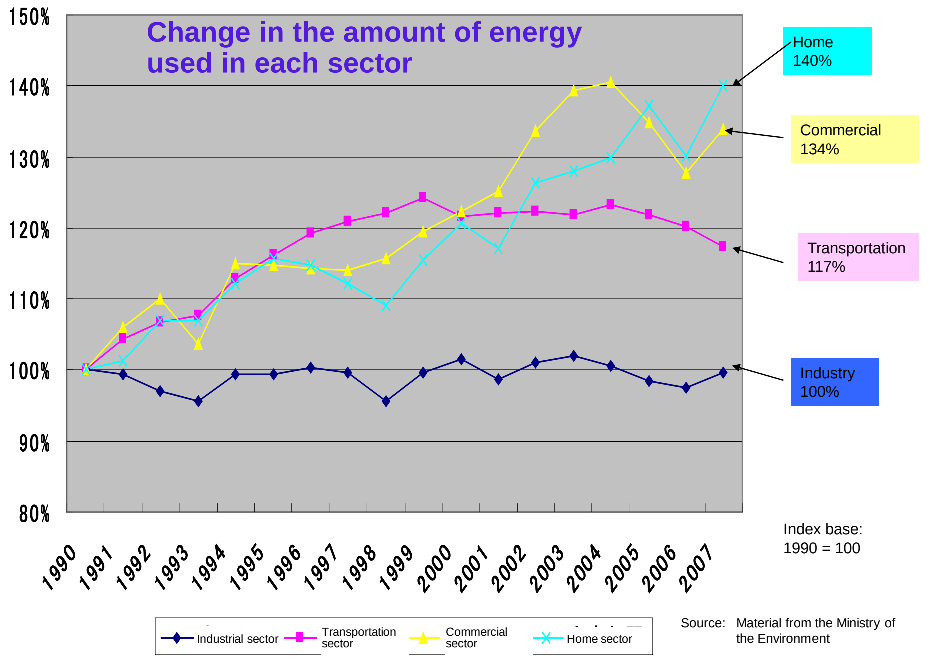


Fig. 3. Change in the amount of energy used in each sector

Overall change in energy conservation initiatives

The chemical industry uses many fossil resources as fuels, and it uses them as raw materials for various types of products as well. To ensure security both in terms of fuels and raw materials after the oil shock, an active approach was taken to energy conservation and substantial energy reductions were pursued until the latter half of the 1980s.

The consumption of ethylene as a raw material for petrochemical products, when converted into energy, shows an increasing trend as a result of the increase in the production volume. However, the amount used as energy (such as fuel) remains flat, and it can be seen that ongoing efforts to conserve energy are being made.

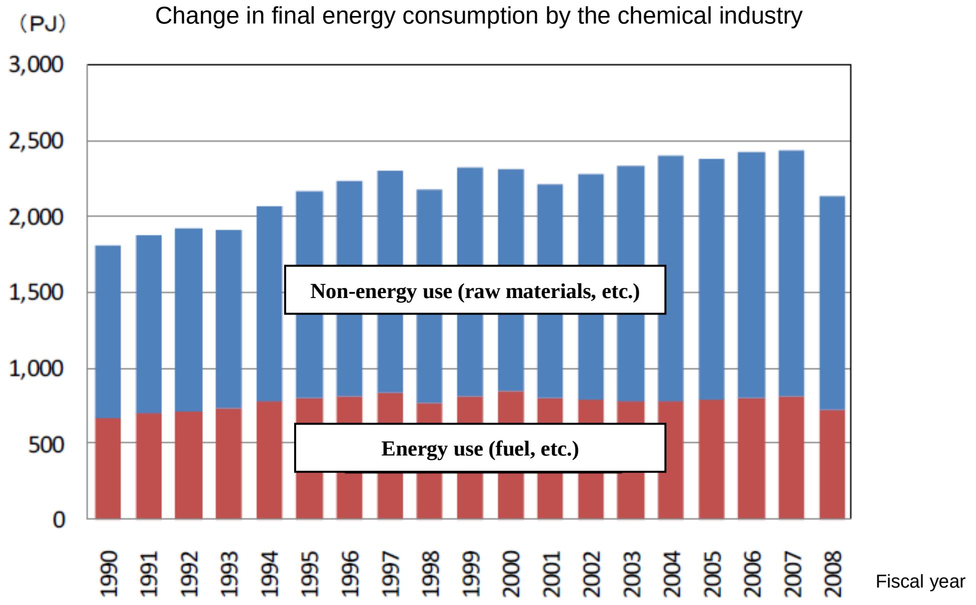


Fig. 4. Change in final energy consumption in Japan [5]

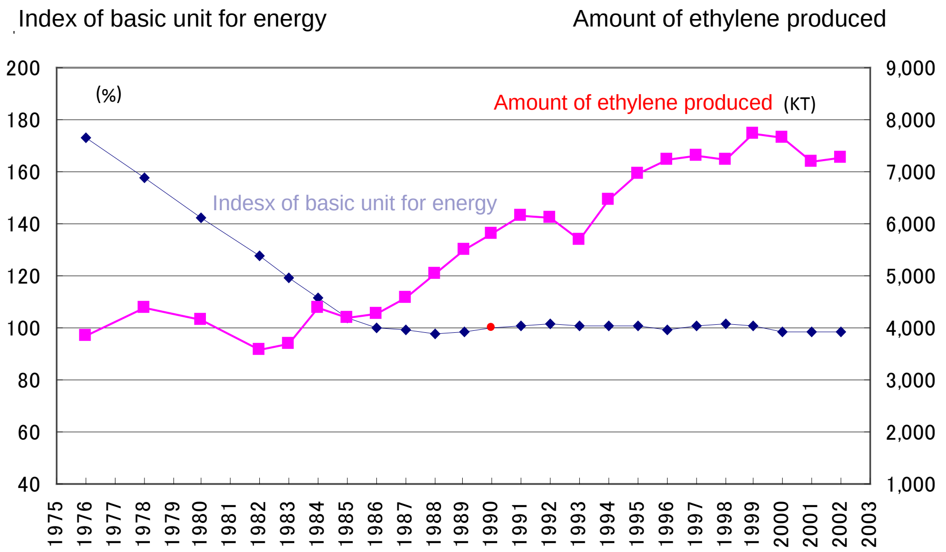
[5] Source: Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, Actual Energy Supply and Demand in FY 2008
http://www.enecho.meti.go.jp/info/statistics/jukyu/result-1.htm

Change in energy conservation initiatives for each product

When each product is analyzed, the basic unit for energy in the production of ethylene reduced to about half by 1990. The basic unit for electricity of caustic soda showed an improvement of about 30%.

Record of achievement by energy-saving activities [1]

(Change in the production amount of ethylene and basic unit for energy in Japan)

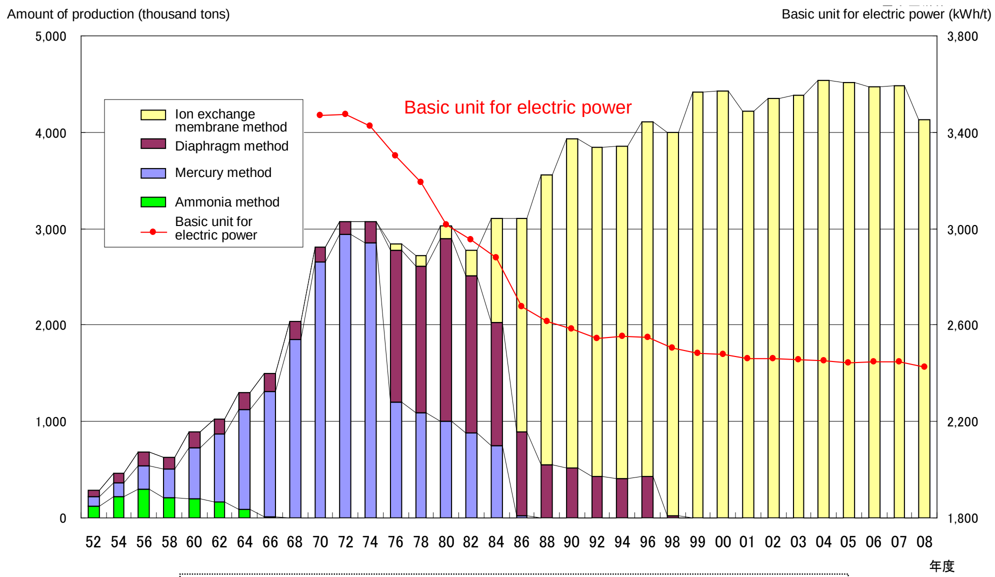


By 1990, achieved improvements in which basic unit for energy was reduced roughly by half

Source: NEDO's Investigational Material for 2003

Record of achievement by energy-saving activities [2]

Change in the amount of caustic soda produced according to each manufacturing method and basic unit for electric power in Japan



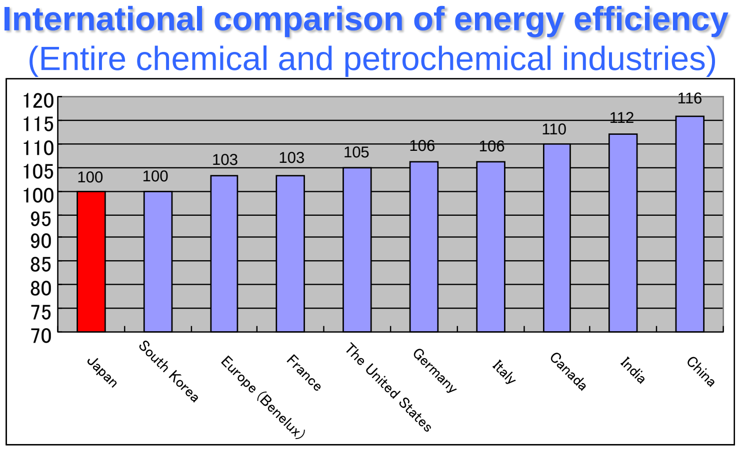
By 1990, the basic unit for electric power was improved by about 30%, and at the same time in 1999, almost 100% was switched to the ion exchange membrane method, which was the state-of-the-art technology

Fig. 5. Changes in basic units in the manufacturing processes of ethylene and caustic soda in Japan

(3) International comparison of energy efficiency of the chemical industry

Overall international comparison of energy efficiency

The chemical industry actively promoted energy conservation initiatives after the oil shock. These initiatives included [1] switching manufacturing methods, process development, [2] improving facility/equipment efficiency, [3] improving the methods of operation, [4] collecting discharged energy, [5] streamlining the processes, etc. As a result of these initiatives to conserve energy, the chemical/petrochemical industries as a whole have achieved the highest level of energy efficiency in the world.



Source: IEA Energy Efficiency Potential of the Chemical & Petrochemical sector by application of Best Practice Technology Bottom up Approach -2006 including both process energy and feedstock use -

Fig. 6. International comparison of energy efficiency in the chemical industry

International comparison of the energy efficiency of each product

Classification of energy consumption in the chemical industry according to its business model shows that petrochemical and soda products account for 65% of all products, and their manufacturing processes have achieved the highest level of energy efficiency in the world.

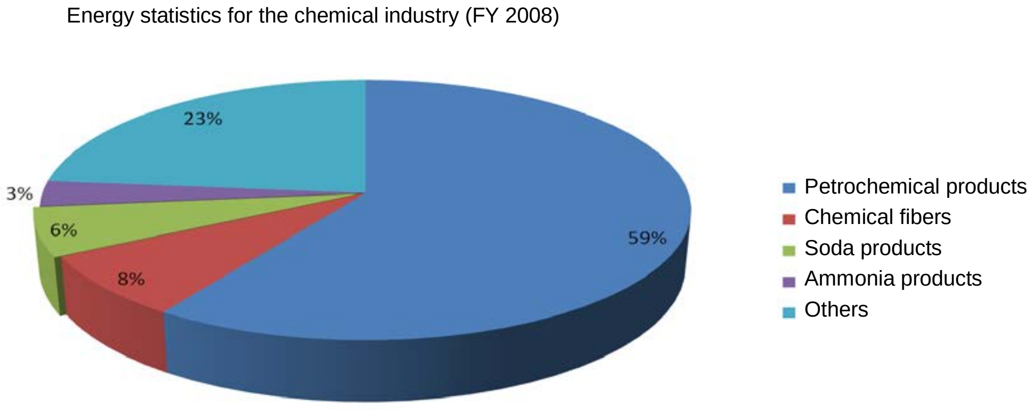


Fig. 7. Details of energy consumption in the chemical industry in each sector (FY 2008)

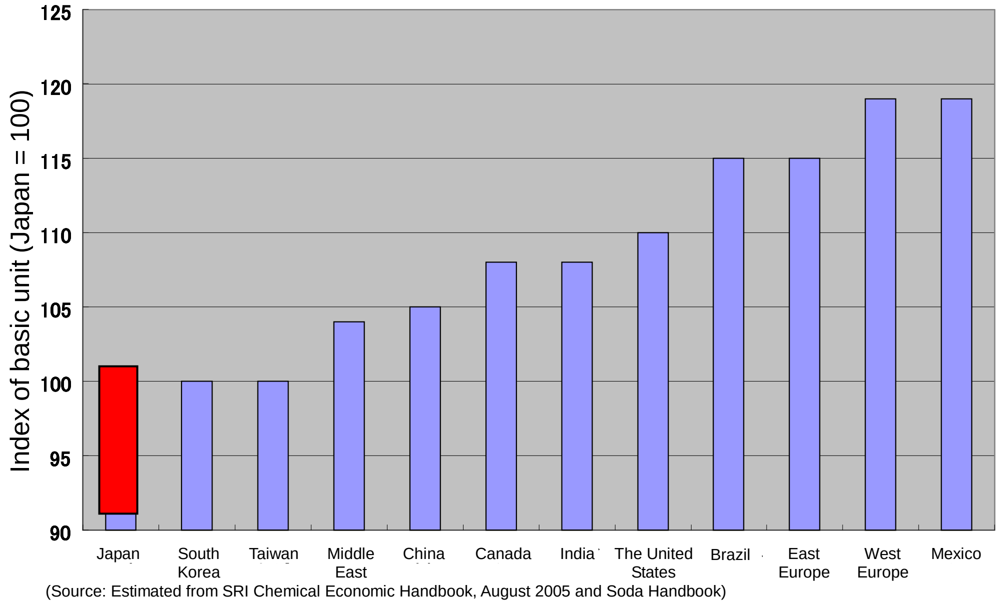


Fig. 8. Comparison of energy efficiency for caustic soda among various countries
(basic unit for electric power for electrolysis, FY 2004)

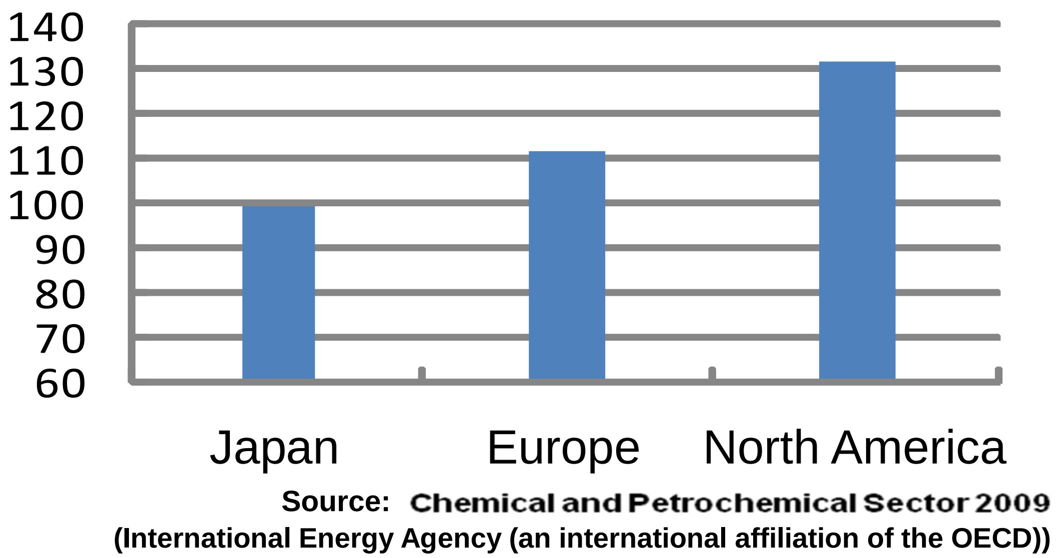


Fig. 9. Comparison of energy efficiency for ethylene plants among various countries (basic unit for energy)

The chemical industry will continue its energy conservation initiatives, and at the same time will continue to promote energy conservation saving and the reduction of CO_2 emission through the following initiatives: [1] propagation of the state-of-the-art facilities when upgrading production facilities and of BPT (Best Practice Technologies) that reach the highest level in the world (more specifically building energy conservation process technologies for ethylene crackers), [2] achievement of the best fuel mix, [3] effective utilization of waste, [4] utilization of renewable energy such as biomass, etc. to conserve energy and to reduce CO_2 emission even further.

(4) Chemical industry - initiatives to reduce CO_2 emission through voluntary action

[1] Improvement in the index of basic unit for energy

The Japan Business Federation has autonomously been taking a responsible approach to solving the problems of global warming since the establishment of its Global Environment Charter in 1991. In particular, in 1997, prior to the adoption of the Kyoto Protocol, it devised the Voluntary Action Plan on the Environment (FY 1997 - FY 2012), and has been making an effort to reduce CO_2 emission in Japan, focusing on the industry and energy sectors. The chemical industry also participated in the "Japan Business Federation - Voluntary Action Plan on the Environment" at the beginning of FY 1997, engaging in work to improve the index of basic unit for energy, and achieved its initial target in FY 2002. In FY 2007, the non-binding target value was reviewed, and vigorous efforts are being made to achieve the target.

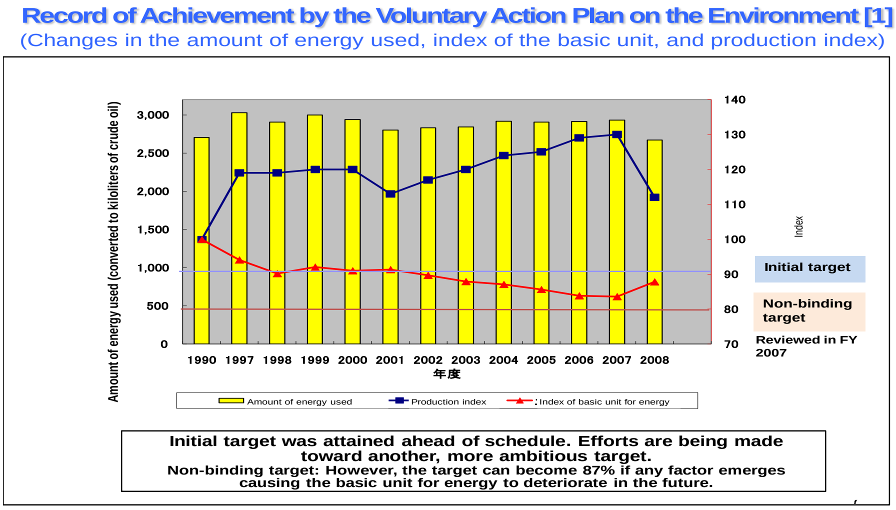


Fig. 10. Change in the indexes of basic unit in the chemical industry

[2] Reduction of GHG emissions

As a result of implementing measures to reduce GHG emissions, a reduction of 26% was achieved in 2008 compared with the reference year (FY 1990 for CO_2 and calendar year 1995 for three alternatives to Freon[6]). Regarding the three alternatives to Freon in particular, the efforts to reduce emissions have included a review of the working processes, strengthening of daily inspections, and systematic renewal of facilities. At the same time, facilities to remove toxins through the combustion of diluted exhaust gases have been installed by utilizing subsidies from the national government, resulting in a substantial reduction in emissions.

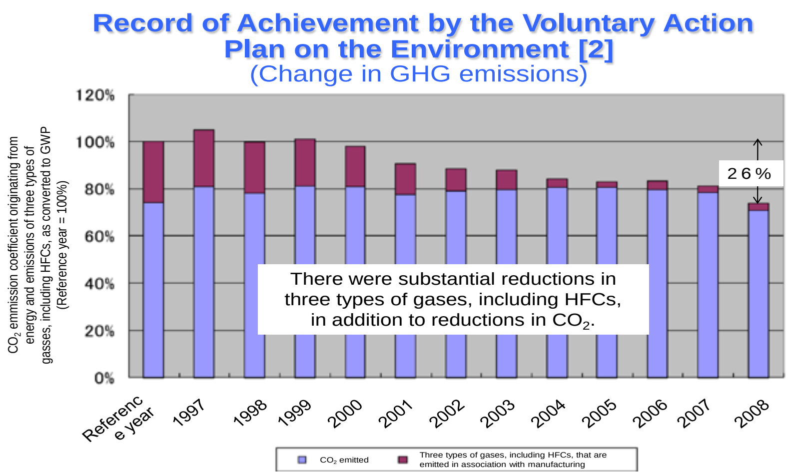


Fig. 11. Change in GHG emissions in the chemical industry

6 HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF_6 (sulfur hexafluoride).

2. c-LCA (carbon-Life Cycle Analysis)

2.1 Method of analysis

CO_2 emission throughout a life cycle becomes the total emissions from extraction, through manufacture, distribution and product use to recycling/disposal.

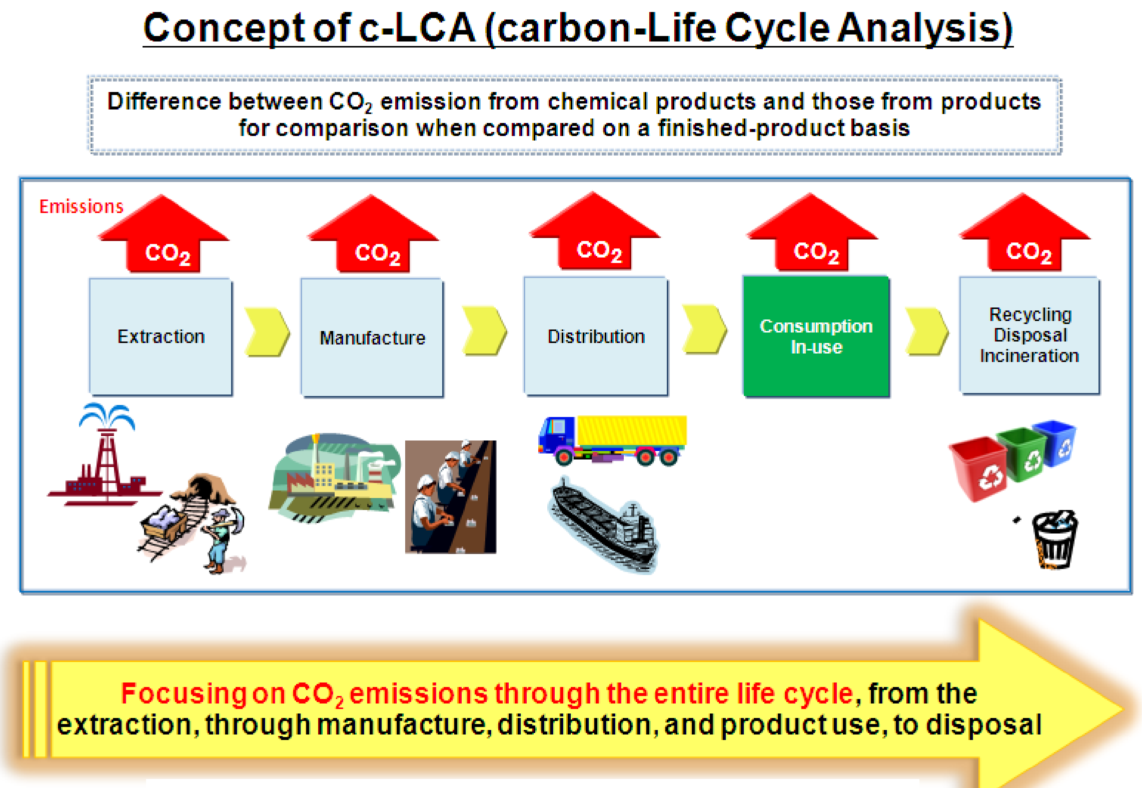


Fig. 12. Concept of c-LCA

The chemical industry uses fossil resources as fuels and emits a lot of greenhouse gases, while supplying materials to other industries. The method of analysis using c-LCA focuses on the CO_2 emitted during use of the products in other industries. It compares emissions over the life cycle of the finished products that use the chemical products with those of finished products that use the products for comparison, and calculates the difference between them as the avoided CO_2 emission by regarding the difference as the increase in emissions when the chemical products are not available.

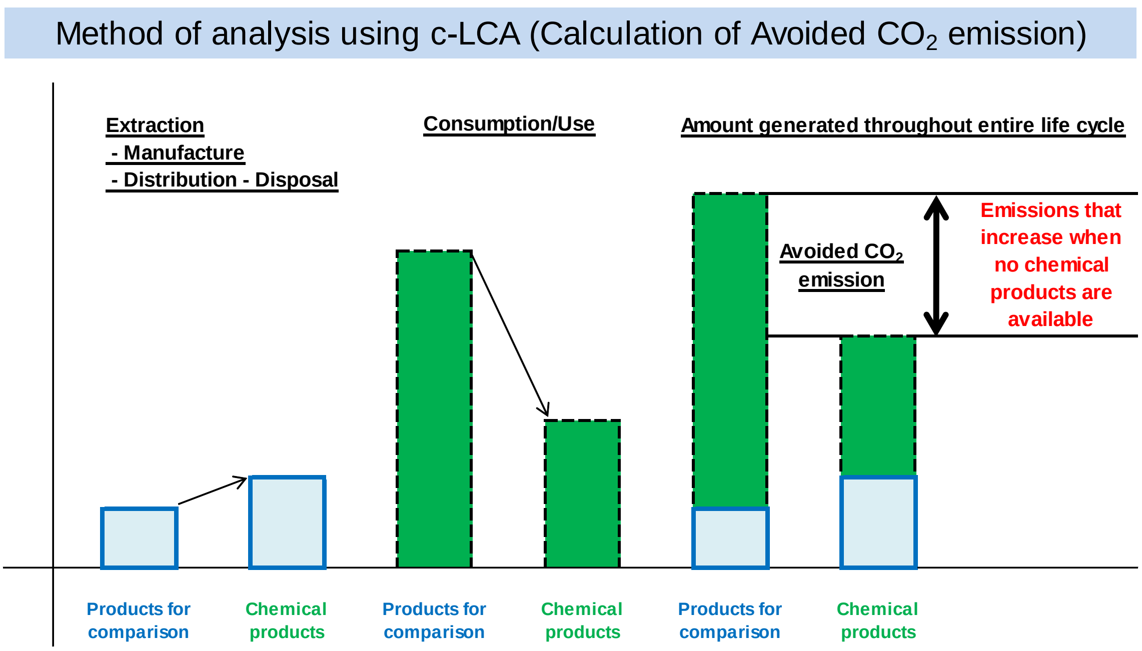


Fig. 13. Method of analysis using c-LCA

Note that, at the time of calculation, if the emissions of chemical products and products for comparison are the same in the process being considered, such as that at the time of the manufacture of finished products (e.g. construction work for housing), the difference becomes zero and calculation of the absolute values may be omitted.

2.2 c-LCA report of ICCA[7]

(1) Purpose and overview

From now on, when implementing a reduction in CO_2 emission, only the efforts for energy conservation/reduction in CO_2 emission during manufacture that have been focused earlier are not sufficient. It has become important to solicit help in reducing CO_2 emission from society at large through the development and propagation of products that lead to the reduction of CO_2 emission in the consumer sector, commercial sector and elsewhere.

From this point of view, based on earlier discussions that consider the reduction in CO_2 emission in the manufacturing sector, the ICCA published its c-LCA report, entitled "Innovations for Greenhouse Gas Reductions[8]", in July 2009 as a call to arms for reducing CO_2 emission. The report offers a new perspective that provides a bird's eye view of a product's entire life cycle from extraction, through manufacture, distribution and consumption, to recycling/disposal.

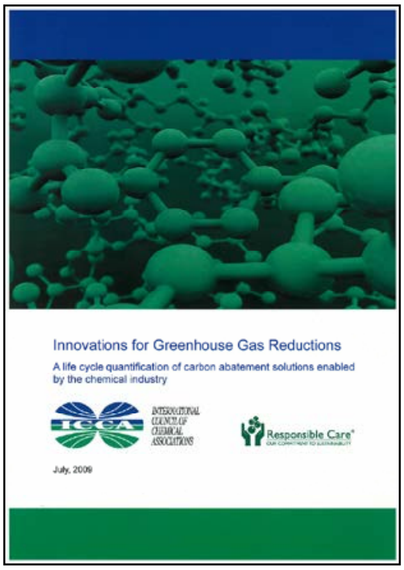
The c-LCA herein means a comparison of the CO_2e emissions (where "e" stands for equivalent; carbon dioxide equivalent to greenhouse gases) of chemical products in specific applications around the world. It spans the stages of extraction, manufacture, distribution, product use, and disposal. The comparison is made with the CO_2e emissions of alternative products that are second-best products other than those produced in the chemical industry. CO_2e life cycle analysis is carried out on more than 100 examples of use of chemical products to evaluate the influence of chemical products on the carbon balance in society overall.

Note that, to ensure objectivity and transparency, the c-LCA of ICCA adopts the method proposed by McKinsey & Company, and all the data for each field quantified through numerical analysis was verified by the Öko-Institut, a German third-party organization.

The c-LCA report

"Innovations in Greenhouse Gas Reductions"

Title of the Japanese translation of the report: "New Perspective Toward Greenhouse Gas Reductions"



(2) Result of analysis for 2005

Global CO_2 emission in the chemical industry

As a result of c-LCA, emissions related to the chemical industry converted to CO_2 in 2005 were 3.3 billion tons worldwide. The majority of this volume, 2.1 billion tons, was produced as a result of the chemical industry purchasing raw materials and manufacturing chemical products. The figure also includes 400 million tons of three alternatives to Freon[9] which have a substantial greenhouse effect.

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[7] International Council of Chemical Associations

[8] Title of the Japanese translation of the report: "New Perspective Toward Greenhouse Gas Reductions"

[9] HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF_6 (sulfur hexafluoride).

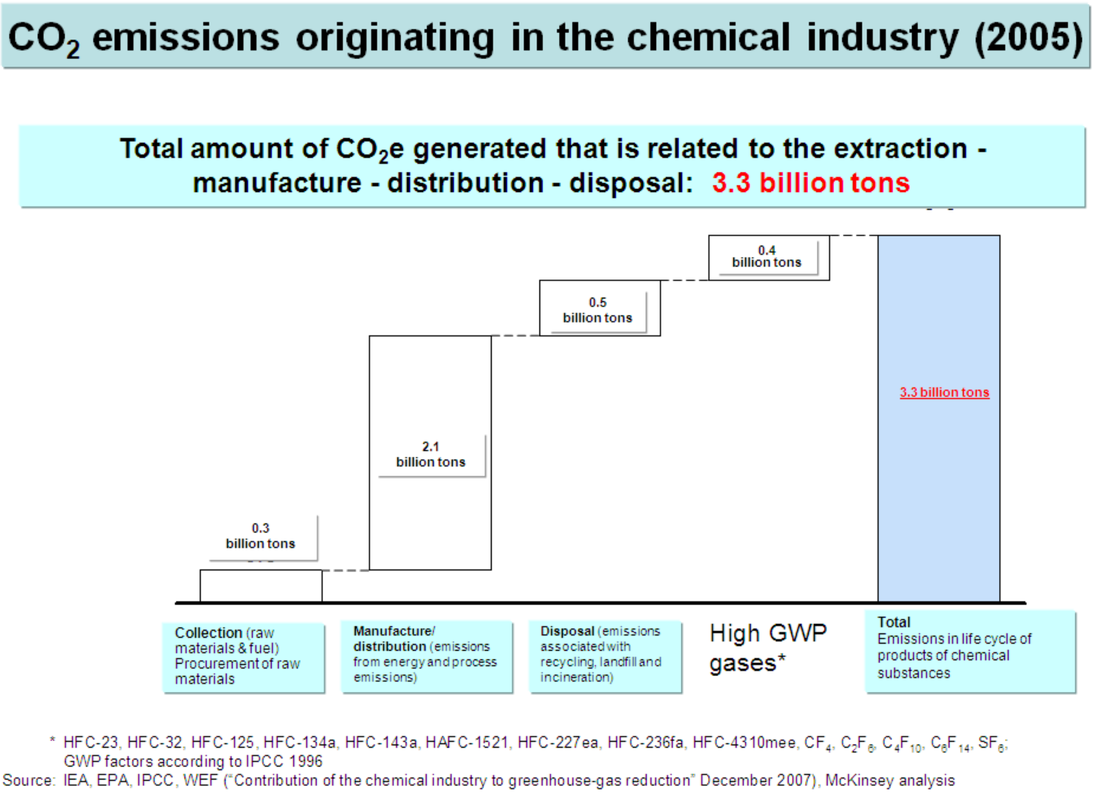

Fig. 14. CO_2 emission originating in the chemical industry in 2005 (global)

Avoided CO_2 emission

Based on the result of c-LCA, the avoided CO_2 emission in the chemical industry in 2005 was 3.6 billion tons, which surpassed the 3.3 billion tons emitted throughout the product life cycle, excluding product use. The two examples that had the largest avoided CO_2 emission were thermal insulation materials and lighting.

In the field of agriculture, there were great variations in agricultural technology according to countries or regions, and it was difficult to obtain a common understanding of the effect of reduced CO_2 emission in agricultural materials, such as agricultural chemicals and fertilizers. Therefore, the figures for the field of agriculture were excluded from the total.

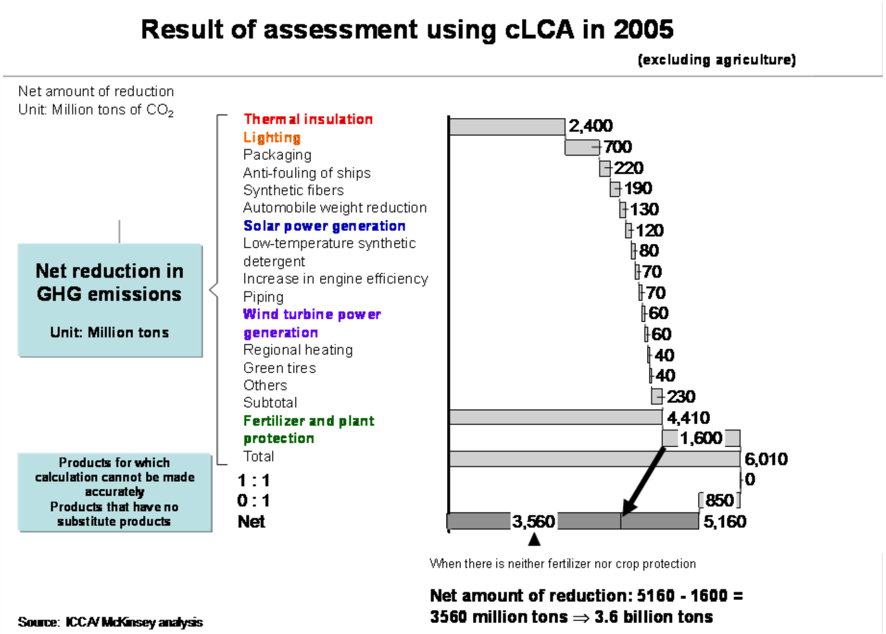

Fig. 15. Avoided CO_2 emission in 2005

(3) Result of evaluation for 2030

Expected global CO_2 emission in the chemical industry

Emissions in the BAU case (business-as-usual: the case in which the present regulations and life style remains unchanged and the efforts to conserve energy continue as at present) in 2030 originating from the chemical industry and emissions on a best-effort basis incorporating the use of innovative technologies that are expected to be realized in 2030 and possible regulations are given.

In the BAU case for 2030, with 2005 as start point, the portion of improvements in production efficiency was excluded from the portion of increased production based on BAU, and the portion of increase in emissions associated with moving production bases was added. As a result, it is expected that emissions will nearly double.

In the case of a best-effort basis, calculation was made by taking account of the effect of reduction through measures such as a proactive introduction of functional products as compared to the BAU case and emissions that will increase as a result of producing such functional materials themselves. As a result, it is expected that the nearly doubling of emissions will be able to be being controlled to 1.5 times.

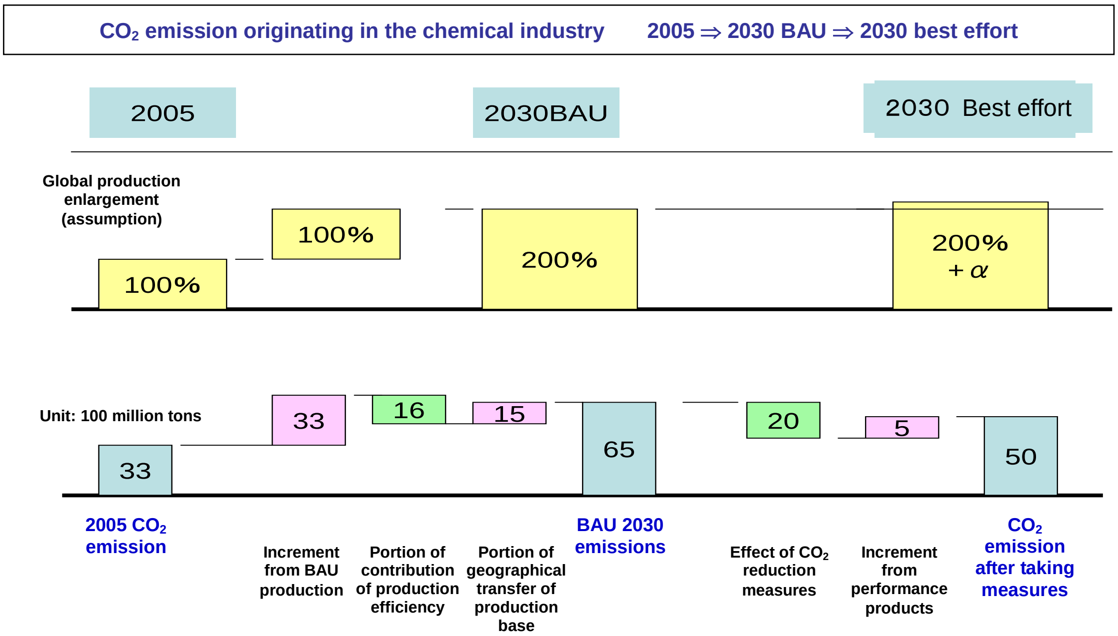

Fig. 16 CO_2e emissions originating in the chemical industry in 2030

Avoided CO_2 emission

The avoided CO_2 emission in 2030 is estimated to be 16 billion tons in total, excluding CO_2 emission from agricultural materials. The greatest abatements are from thermal insulation materials (6.8 billion tons), followed by lighting apparatus (4.1 billion tons) and solar power generation (2 billion tons).

Global anthropogenic GHG emissions in 2005 are estimated to have been around 46 billion tons (WEF 2007[10]), and a reduction of 16 billion tons translates into a reduction of about one third.

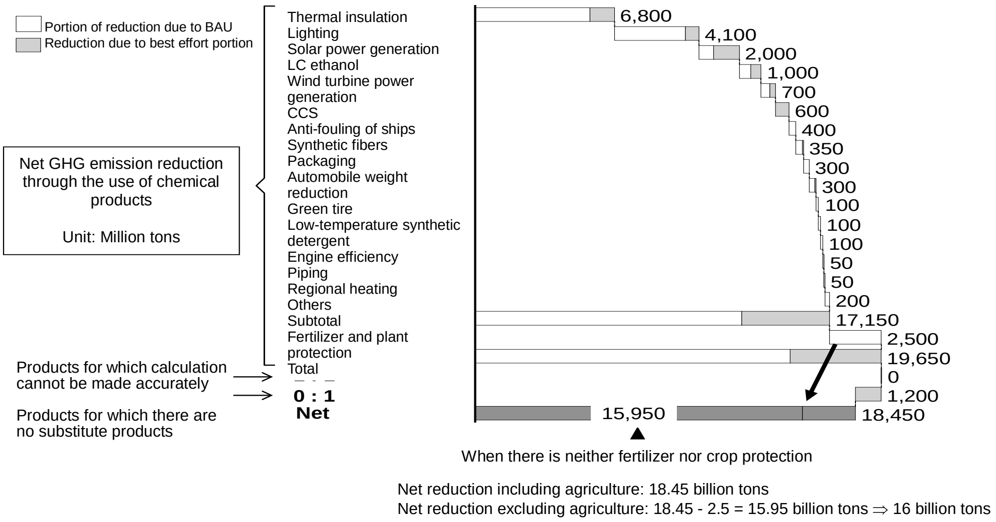

Fig. 17. Avoided CO_2 emission in 2030 (on a best-effort basis)

"Summary"

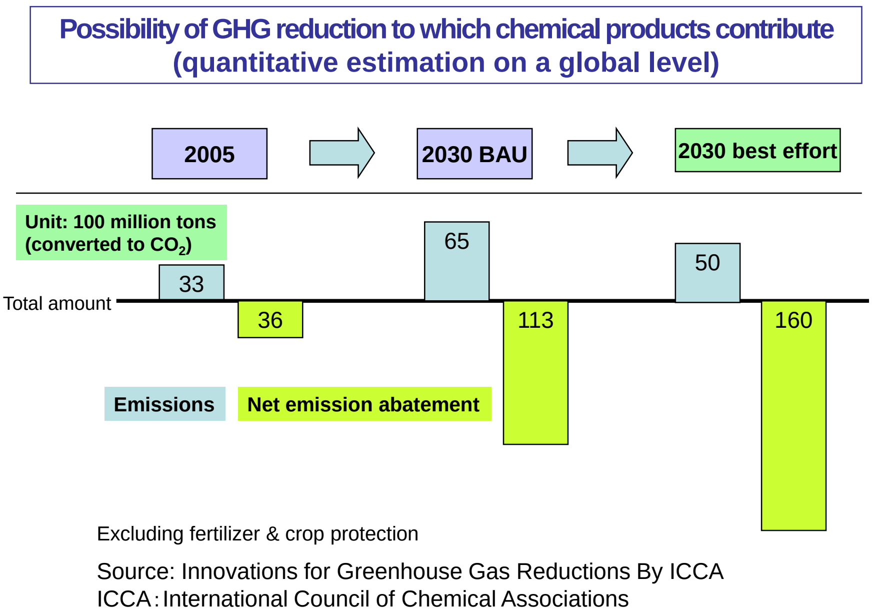

Fig. 18. Summary of emissions originating from the chemical industry and avoided CO_2 emission in 2030

10 World Economic Forum 2007 (commonly known as the Davos Forum)

3. Analysis using c-LCA in Japan

3.1 Background and purpose

According to the timetable for the New Growth Strategy that was published in August 2010 by the Ministry of Economy, Trade and Industry, 2020 is set as the mid-term target for preventive measures against global warming. In addition to the initiatives to conserve energy and to reduce CO_2 emission during the manufacturing stage as described above, the chemical industry strives to help reduce CO_2 emission in the stage of the use of final products that use chemical products and to help reduce CO_2 emission in society as a whole through cooperation between different types of businesses.

The ICCA report calculated the global avoided CO_2 emission in 2005 and 2030 in the chemical industry worldwide. The purpose of the current report is to evaluate specific examples of chemical products in Japan and to indicate the circumstances of CO_2 emission by taking account of the timetable for the New Growth Strategy of the Ministry of Economy, Trade and Industry.

[1] Paying attention to the timetable for the New Growth Strategy of the Ministry of Economy, Trade and Industry, **the year 2020,** which is the period considered in the timetable, has been adopted as the target fiscal year.

[2] The avoided CO_2 emission through the use of specific chemical products **in Japan** in 2020 has been quantified.

Although the current report deals with the nine examples for which LCI[11] data were published and for which supporting data is available, examples will be expanded hereafter with an expansion of the LCI data. To attain a low-carbon society, quantification of the degree to which the chemical industry contributes to abatement will be promoted, thereby providing a direction for society as a whole to follow with respect to policies on the reduction of emissions.

3.2 Analysis targets

The following nine examples were the targets of analysis using c-LCA on this occasion, considering the fact that [1] LCI data is available in Japan and [2] the ICCA report identifies the use of chemical products as having a major effect on net emission reductions.

The products to be analyzed are based on the present products/technologies, as of 2010, and products that are expected to be in widespread use as of 2020 as a result of technical development are not considered as analysis targets.

Also, comparisons are made with products that have to be used if no chemical products are available. The avoided CO_2 emission is calculated by multiplying the value obtained based on this by the expected volume of manufacture as of 2020.

Note that avoided CO_2 emission includes the portion for chemical products as well as the portion for products related to other raw material and related materials. However, no technique is currently available for quantitatively distinguishing portion related to chemical products and the portion related to non-chemical products. Therefore, the avoided CO_2 emission corresponding to each constituent product has not been determined.

Fig. 19 and Table 2 show the chemical products for which avoided CO_2 emission has been calculated on a trial basis on this occasion and the final products and products for comparison that are targets of analysis using c-LCA.

[11] Life Cycle Inventory: environmental burden from manufacture to disposal

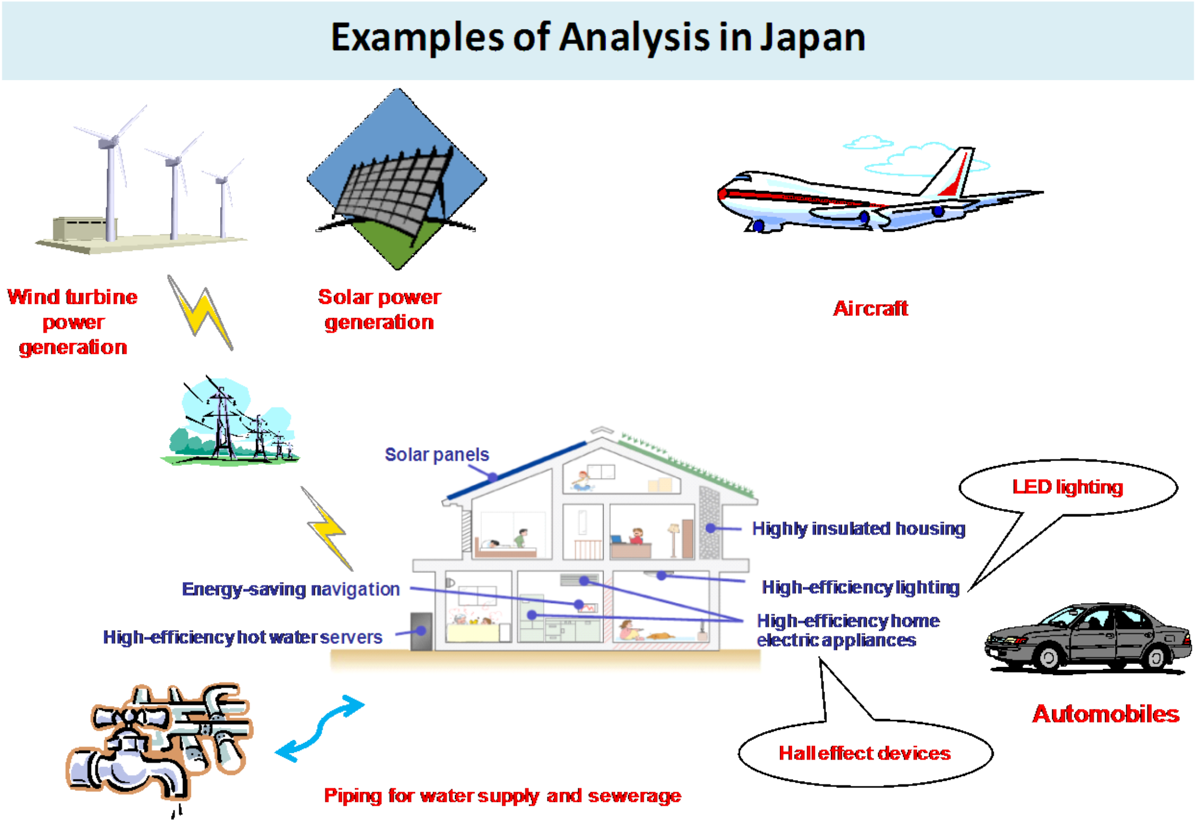

Fig. 19. Diagrams of the products to be analyzed

Classification	Chemical product	Final product	Object of comparison
Renewable energy	Materials for solar power generation	Solar power generation facilities	Electric power utilities
	Materials for wind turbine power generation	Wind turbine power generation facilities	Electric power utilities
Improvement in fuel economy through weight reduction	Automotive materials	Automobiles (carbon fiber)	Automobiles (steel)
	Materials for aircraft	Aircraft (carbon fiber)	Aircraft (aluminum alloy)
Energy conservation	LED-related materials	LED light bulbs	Incandescent light bulbs
	Thermal insulation materials for housing	Housing (using thermal insulation materials)	Housing (not using thermal insulation materials)
	Hall effect device, Hall effect IC	Air conditioners (using DC brushless motors)	Air conditioners (not using AC motors)
	Piping materials	PVC pipes	Ductile cast iron pipes
	Materials for seawater desalination plant	Materials for seawater desalination plants (RO membrane)	Materials for seawater desalination plant (evaporation method)

Table 2. List of products to be analyzed

3.3 Approaches concerning the analysis period

[1] **Evaluate the avoided CO_2 emission when the products manufactured in the analysis year have been used until the end of their life.**

[2] Evaluate the avoided CO_2 emission as a result of operation, for the analysis year, resulting from the total number of product units that will be distributed and put into operation until the analysis year.

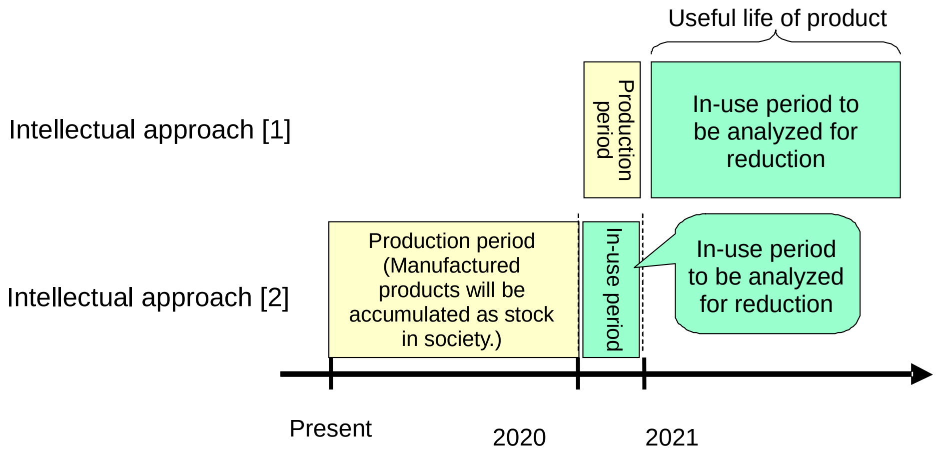

Fig. 20. Two ways of thinking concerning the analysis period

In the analysis using c-LCA, as the objective is to understand the potential for chemical products to reduce emissions, it has been decided that approach [1] should be adopted based on **the products to be manufactured during the year of 2020,** which is the reference year.

3.4 Calculation of the avoided CO_2 emission

(1) CO_2 emission factor

Since it is difficult to predict the level of technologies of conventional products in 2020, as for the CO_2 emission of alternative products that become the object of comparison, **data of past performance that can be determined as of 2010** have been used. (Except CO_2 emission factor for electric power utilities)

(2) Geographical conditions

The effect of the abatement of CO_2 emission resulting from the use of products under analysis has been limited to that **in Japan** as a general rule. However, as the main markets for seawater desalination plants are located overseas, evaluation has been made based on worldwide use.

(3) Method of calculation

Using cases where conventional products are manufactured as the baseline, the avoided CO_2 emission is calculated by multiplying the difference when conventional products have been replaced with the products under analysis according to the quantity manufactured during the reference year.

Step 1: Calculate the avoided CO_2 emission per unit quantity (e.g. kg, item) of the products under analysis.

CO_2 emission over the life cycle per unit quantity of the products being analyzed
- CO_2 emission over the life cycle per unit quantity of the products for comparison = A

Step 2: Calculate the avoided CO_2 emission by multiplying A by the quantity of products under analysis to be introduced in 2020.

Emission abatement of A × Quantity of products under analysis that are expected to be manufactured in 2020 (one year)

4. Examples of analysis (CO_2 emission calculated by setting certain conditions)

4.1 Renewable energy 1 - materials for solar power generation

(1) Overview of solar power generation

A solar cell is a device that directly converts energy from the sun into electrical energy by utilizing the principle of a semiconductor. A solar power generation system consists of a solar cell, a power conditioner that converts electric power from direct current to alternating current, and the structure for installing solar cells on the roof.

A solar power generation system is a system that can generate power in any place and can be of an arbitrary size. The system can be used in ordinary housing, making its use more widespread. There are strong expectations that solar power generation will become an important technology for solving environmental problems such as the depletion of fossil resources and global warming.

[1] Nature of the reduction in CO_2 emission

No CO_2 is emitted during power generation because no fossil fuels are used.

[2] Types and features of solar cells

- Crystalline silicon based: Mainstream at present. Achieves high conversion efficiency. The largest in distributed quantity.
- Silicon thin-film based: Low cost
- Compound semiconductor based: No silicon is used. Lower cost and improvement in conversion efficiency are expected.

[3] Power generation efficiency (efficiency of conversion from solar energy into electrical energy)

- Present: Efficiency of crystalline silicon based module up to around 16%[12]
- Future: Target for 2025 - NEDO Technology Development Roadmap

Crystalline silicon based	25%
Compound based	40%

[4] Amount of solar power delivered in Japan

- FY 2009: About 1.7 million kW[13]

  Details According to destination: Overseas about 1 million kW, Japan about 0.7 million kW
  According to type: Total of multicrystalline and monocrystalline silicon
  1.46 million kW (90% of the total amount delivered)
- Cumulative amount introduced up to 2007: Global 7,841 MW, Japan 1,919 MW

[5] Examples of chemical products in solar power generation systems

The major chemical products that constitute the module of a solar cell are multicrystalline silicon, the back seat (resin) and the sealing material (resin), and these materials have been used as the targets of calculation.

- Multicrystalline Si, Si wafer, SiH_4 gas
- Sealing materials for solar cells (ethylene vinyl acetate copolymer, phenolic resin)
- Back seat for solar cells (polyvinyl fluoride, PET)
- Various types of chemicals (detergent, resist stripper)
- Diethylzinc, BCl_3, CVD materials
- Ceramic printed circuit boards for inverters, heat sinks

[12] Source: New Energy and Industrial Technology Development Organization (incorporated administrative agency) Report on the "Review and Study Committee Concerning the "Solar Photovoltaic Generation Roadmap toward 2030 (PV2030)" (Solar Power Generation Roadmap PV2030+) (June 2009)

[13] Source: Japan Photovoltaic Energy Association, Shipment volume of solar cells (May 2011) http://www.jpea.gr.jp/04doc01.html

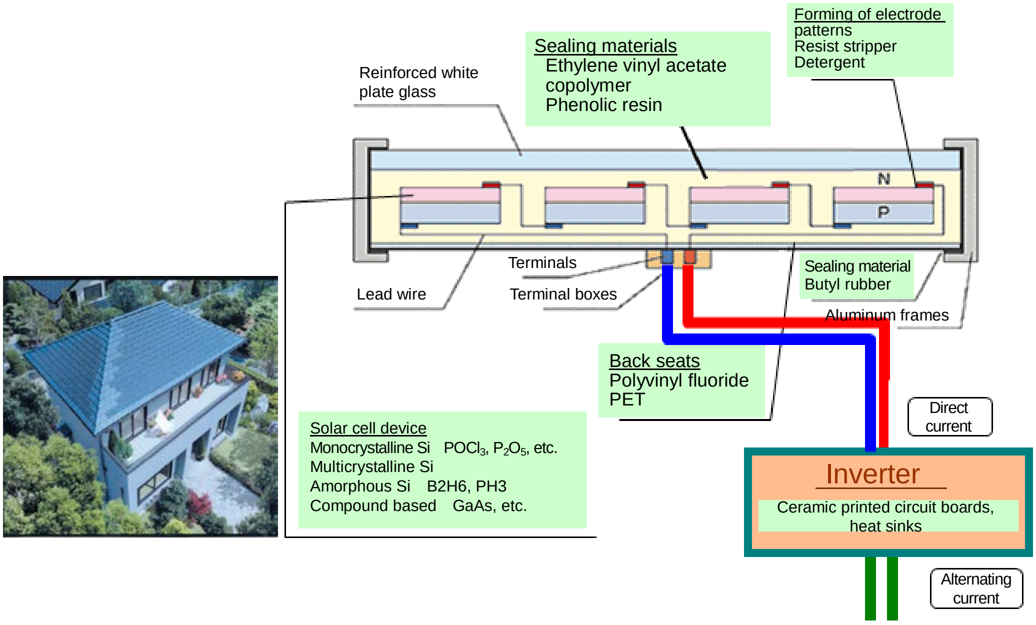

Fig. 21. Example of solar power generation system construction

(2) Analysis conditions

[1] Analysis targets and comparison targets

A comparison was made between the CO_2 emission when generating 1 kWh using a solar power generation system and those using electric power utilities, and the reduction in CO_2 emission was calculated.

- Analysis target: Multicrystalline silicon solar cell (because its has the highest share in Japan)
- Comparison target: Electric power utilities (power source mix with thermal power, nuclear power, hydropower, etc. Based on average composition in power generation plants in Japan)

[2] System boundaries (scope of analysis)

The analysis of solar power generation included all emissions related to extraction, through manufacture, use, maintenance (parts replacement) to disposal using multicrystalline silicon solar cells. Regarding disposal, it was assumed that the aluminum frame and terminal box (including the cable for wiring) are removed from the dismantled/collected solar cell module and recycled by a recycling service supplier. Other modules were assumed to be treated as industrial waste and after intermediate treatment, those that can be recycled would be recycled, and those that cannot be recycled would ultimately be disposed of in landfill.

The analysis of electric power utilities included all emissions from power generation systems using the power source mix and from extraction, through manufacture, use, maintenance (parts replacement) to disposal for fuel production, fuel transportation, and waste disposal.

[3] Criteria for calculating the effect of emission reduction

- CO_2 emission of chemical products

  Calculations were made concerning the excavation of SiO_2/manufacture of Si metal - manufacture of crystalline Si wafer, procurement of raw materials - manufacture of sealing materials and back seats. The portion of CO_2 emission factor for solar power generation that was included in the calculation was extracted.

- CO_2 emission factor (amount of CO_2 emitted per kWh of power generation)
  Solar power generation: 0.047 kg-CO_2/kWh[14]
  Electric power utilities: 0.33 kg-CO_2/kWh[15] Electric power emission factor at the power receiving end as of 2020
- Conditions of the amount of solar radiation: Tokyo
- Life of the solar power generation system: 20 years
- Annual reduction in CO_2 emission per unit degree of use (rated output of solar power generation: 1 kW)
  Difference between CO_2 emission from electric power utilities and those from solar power generation at the time of power generation of 1 kWh
  × Annual amount of power generation per kW of output

(3) Result of analysis

[1] Result of analysis using c-LCA per unit (solar power generation output 1 kW)

Chemical product CO_2 emission from extraction to manufacture

Total of the portions indicated in blue in Table 3 : **735 kg-CO_2/kW**

Calculation was made on unprocessed materials/material-related products for which effective data is available. The calculated values are included in the solar power generation CO_2 emission factor.

	Analysis target	Comparison target
	Solar power generation	Electric power utilities
1) CO_2 emission in stages from extraction to manufacture (kg-CO_2/kW)		
• Manufacture of SiO_2 transportation and Si metal[14]	57.95	Included in the CO_2 emission factor (0.33kg-CO_2/ kWh)
• Multicrystalline Si agglomerate[14]	445.91	
• Manufacture of multicrystalline Si ingot[14]	26.72	
• Manufacture of wafer[14]	145.02	
• Sealing materials[16]	42.9	
• Back seat[16]	16.5	
Total for the manufacturing stage (kg-CO_2/kW)	**735**	–

Table 3. CO_2 emission in the stage of manufacture of solar cells per unit

Calculation of avoided CO_2 emission

Based on the annual amount of power generated using sunlight condition in Tokyo, the difference between CO_2 emission from solar power generation and those from electric power utilities has been used as the avoided CO_2 emission.

- Annual amount of power generated: 902 kWh/year/kW[14] per kW of output from solar power generation when the conditions of sunlight condition in Tokyo are applied
- Annual reduction in CO_2 emission: ▲Approx. 255 kg-CO_2/kW/year
  Difference from power generated by electric power utilities when output of 1 kW is introduced
- Avoided CO_2 emission: ▲5,105 kg-CO_2/kW
  Lifetime emission reduction (useful life: 20 years, per kW of output)

[14] Source: Report of Business Entrusted by NEDO Technical Development of Common Foundations for Solar Power Generation Systems
"Investigational Research on the Life Cycle Analysis of Solar Power Generation Systems" (March 2009)
[15] Source: Action Plan for Low Carbon Society Target value of the Federation of Electric Power Companies of Japan
[16] Source: "Solar Power Generation Engineering" (Komiyama *et al.*) P147

	Analysis target Solar power generation	Comparison target Electric power utilities
2) Reduction in CO_2 emission due to solar power generation		
• CO_2 emission coefficient during power generation (kg-CO_2/kWh) (a)	0.047	0.33
• Annual amount of power generation per kW of solar power generated (kWh@Tokyo) (b)	902	902
• CO_2 emission relative to annual power generated per kW of solar power generated (kg-CO_2/kW/year) (a)×(b)	(c) 42.39	(d) 297.66
• Difference in CO_2 emission relative to annual power generated per kW of solar power generated (kg-CO_2/kW/year) (c) – (d)	▲255.27	–
3) Effect of reduction in CO_2 emission over the lifetime of solar power generation (kg-CO_2/kW/20 years)	**▲5,105**	–

Table 4. Reduction in CO_2 emission per unit (solar power generation vs. electric power utilities)

[2] Effect of introduction throughout Japan

The reduction in CO_2 emission in 2020 relative to the degree of use throughout Japan has been calculated.

- Degree of use for the year 2020: 1.76 million kW
  Since the reduction in CO_2 emission varies greatly according to the degree of use, consideration was given to prevent the evaluation from becoming excessive. The difference between the cumulative degree of use of solar power generation systems[17] in 2005 and that in 2020 was calculated, and the average increment for one year obtained by dividing the difference by 15 years is assumed to be the degree of use.
- CO_2 emission during the manufacturing stage of chemical products: 1.29 million tons
  The component included in the effect of emission reduction was obtained by multiplying the emissions per kW 735kg-CO_2 by the degree of use, 1.76 million kW.
- Effect of reduction in CO_2 emission over the lifetime of solar power generation to be produced in 2020: ▲8.98 million tons
  The reduction in emissions has been estimated by multiplying the degree of use for the year 2020, 1.76 million kW, by the effect of reduction in CO_2 emission over lifetime per kW, ▲5,105 kg-CO_2/kW/20 years.

1) Degree of use in 2020	
• Actual cumulative degree of use in 2005 (1,000 kW)	1,400
• Predicted cumulative degree of use in 2020 (1,000 kW)	27,800
Annual average increment until 2020 (1,000 kW) → Amount of production during the year 2020	1,760
2) Chemical products emissions from extraction to manufacture (2020) (1,000 t-CO_2)	1,290
3) Effect of lifetime reduction in CO_2 emission (2020, portion of use for 20 years) (1,000 t-CO_2)	▲8,980

Table 5. Reduction in emissions as of 2020

[17] Source: Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy "On Framework of the Total Buy Back System for Renewable Energy" (August 4, 2010) http://www.meti.go.jp/committee/summary/0004629/framework03.pdf

4.2 Renewable energy 2 - materials for wind turbine power generation

(1) Overview of carbon fiber

PAN-based carbon fiber is a carbon material in the form of a fiber that has a minute graphite crystalline structure. It is obtained by polymerization and using heat treatment to create a yarn of acrylonitrile for which the raw material is naphtha. It is widely used in various applications because it is lightweight with strong mechanical performance (high specific strength, high specific modulus of elasticity) and because of its unique carbon-based properties, which include low density, low coefficient of thermal expansion, heat resistance, corrosion resistance, chemical stability, X-ray permeability and self-lubricating properties.

It is rare that carbon fiber is used individually. It is usually used as a composite material having matrixes of resin, ceramics, metal, etc. Especially, a composite material made by immersing resin into carbon fiber, CFRP (Carbon Fiber Reinforced Plastic), is widely used.

This report evaluates the reduction in the environmental burden obtained by using this CFRP compared with the use of conventional materials in the applications in which CFRP is used, in particular, applications in wind turbine power generation (to be evaluated in this section), applications as automotive materials (Section 4.3) and applications as aircraft materials (Section 4.4).

(2) Overview of wind turbine power generation

Wind turbine power generation has been used as a natural form energy since olden times, and it is expected that this form of clean energy will assist in the preventive measures against global warming.

Aside from the medium and large-scale windmills, there are various sizes of power generation including a small generator that can generate power in a facility. However, the largest growth is expected with ultra-large power generators of 3 MW or more, and these devices are being introduced mainly in Europe, America and Asia. From now on, it is expected that the system will become increasingly large because the power generation capacity is proportional to the square of the blade length. Development of a 10-MW system with a blade length exceeding 70 meters is already underway.

[1] Nature of the reduction in CO_2 emission

Since no fossil fuels are used, no CO_2 is emitted during power generation.

[2] Features of wind turbine power generation

- About 40% of the wind energy can be converted into electrical energy.
  Of the various types of natural energy, this energy has relatively high efficiency.
- It has a high utilization rate because, unlike solar power generation, power can be generated even at night.
- Because of its high utilization rate and high conversion efficiency, the cost for power generation is less than that of solar power generation.
- It has a smaller CO_2 emission factor than the other types of natural energy. Also, the CO_2 emission factor is expected be reduced through further improvements in power generation capacity and the use of larger windmill blades.
  Solar power generation: 0.047 kg-CO_2/kWh[18]
  Wind turbine power generation: 0.005 kg-CO_2/kWh[19]

[3] Degree of use of wind turbine power generation systems in Japan[20]

- As of 2009: 2,200 MW
- As of 2020: 5,000 - 7,500 MW. The national government predicts an average annual increase of introduction will be 450 MW/year at the maximum.

[18] Source: NEDO Report of Business Entrusted by NEDO Technical Development of Common Foundations for Solar Power Generation Systems
"Investigational Research on the Life Cycle Analysis of Solar Power Generation Systems" (March 2009)

[19] Source: Report of VESTAS "Life cycle analysis of offshore and onshore sited wind power plants based on VesTas V90-3.0 MW turbines." (June 2006)

[20] Source: Website of the Ministry of Economy, Trade and Industry
http://www.meti.go.jp/committee/summary/0004629/framework.html

[4] Examples of chemical products used in wind turbine power generation

In an ultra-large system for which the power generation capacity is 3 MW or more, it is necessary for the carbon fiber used in the girders for the blades to have a modulus of elasticity at least three times that of conventional glass fiber. This is because it is necessary to prevent the blades from striking the tower when they deflect under the load of the wind[21].

- Carbon fiber
- Epoxy resin

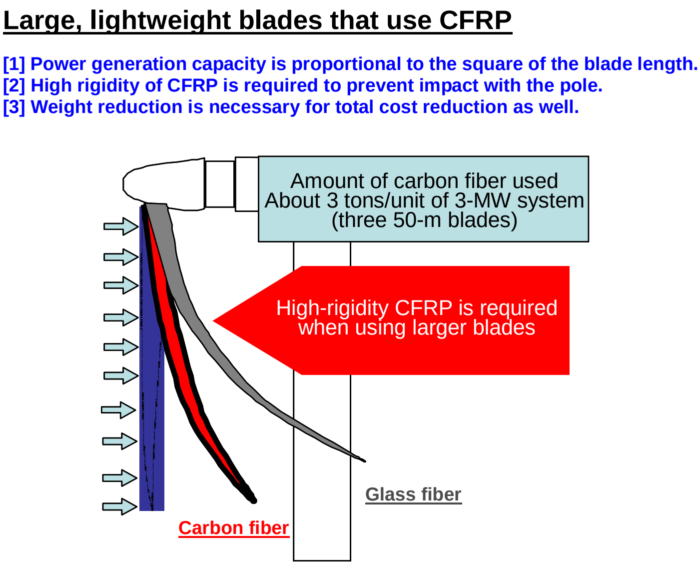

Fig. 22. Comparison between wind turbine blades made of CRFP and those made of glass fiber

(3) Analysis conditions

[1] Analysis targets and comparison targets

In analyzing the use of carbon fiber in wind turbine blades, a comparison was made between the CO_2 emission when electric power of 1 kWh is generated by a wind turbine power generation system and those when electric power of 1 kWh is generated by electric power utilities. From this comparison, the reduction in CO_2 emission was calculated.

- Analysis target: A large wind turbine generator system (3 MW class) using carbon fiber
- Comparison target: Electric power utilities (power source mix of thermal power, nuclear power and hydropower, etc. Based on average composition in power generation plants in Japan)

[2] System boundaries (scope of analysis)

For wind turbine power generation, the analysis included emissions from extraction, through to manufacture, use, and maintenance (parts replacement). The analysis excluded disposal because there is no record of it having been done. Since CO_2 emission with carbon fiber from extraction to manufacture were not taken into account, they were added as an increment during equipment manufacture. However, emissions from materials to be replaced by carbon fiber (e.g. glass fiber) were not excluded.

Regarding electric power utilities, the analysis includes all emissions from power generation systems by means of the power source mix, as well as from extraction, through to manufacture, use, fuel production, fuel transportation and maintenance (parts replacement), to disposal for fuel production, fuel transportation, and waste disposal.

[21] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

[3] Criteria for calculating the effect of emission reduction

- CO_2 emission of chemical products
  Calculations were made concerning the processes from extraction to the manufacture of carbon fiber.
- CO_2 emission factor (amount of CO_2 emitted per kWh of power generation)
  Wind turbine power generation: 0.005 kg-CO_2/kWh[22]
  Electric power utilities: 0.33 kg-CO_2/kWh[23] Electric power emission factor at the power receiving end as of 2020
- Life of the wind turbine power generation system: 20 years
- Amount of carbon fiber used per unit of wind turbine power generator: 3 tons
- Annual reduction in CO_2 emission per unit degree of use (1 unit of wind turbine power generator of 3 MW output)
  Difference between CO_2 emission from electric power utilities and those from wind turbine power generation at the time of power generation of 1 kWh
  × Annual amount of power generation of 3 MW wind turbine power generator

(4) Result of analysis[24]

[1] Result of analysis using c-LCA per unit (1 unit of wind turbine power generator)

Chemical product CO_2 emission from extraction to manufacture

Portions indicated in blue in Table 6 : **60 t-CO_2/unit**

Net increment of carbon fiber per unit. Although the portion of the materials to be substituted (e.g. glass fiber, etc.) is included in the CO_2 emission factor for wind turbine power generation, it is difficult to extract the portion. Therefore, this portion was not excluded from the calculation and the emissions were counted in duplicate.

CO_2 emission per ton of carbon fiber 20 tons
× Amount of carbon fiber used per unit of wind turbine power generator 3 tons

Calculation of avoided CO_2 emission

The annual amount of power generated by using a wind turbine power generator of 3 MW/unit in output was used as the reference. The difference between the CO_2 emission from wind turbine power generation and those from electric power utilities is used as the avoided CO_2 emission.

- Annual amount of power generated: 8,760 MWh/year/unit
  Calculated assuming that the output is 3 MW/unit and the amount of power that can be generated per hour is 1 MW/unit
- Annual reduction in CO_2 emission: ▲ 2,847 t-CO_2/kW/year
  Difference from power generated by electric power utilities when output of 3 MW/unit is introduced
- Avoided CO_2 emission: ▲56,940 t-CO_2/kW
  Lifetime emission reduction (useful life: 20 years, per unit of facility of 3 MW in output)

	Analysis target	Comparison target
	Wind turbine power generation (3 MW class)	Electric power utilities
1) CO_2 emission at the stages of extraction to the manufacture of carbon fiber (t-CO_2/unit)	**60**	–
2) Effect of reduction in CO_2 emission due to wind turbine power generation		
• CO_2 emission coefficient during power generation (kg-CO_2/kWh) (a)	0.005	0.33

22 Source: Report of VESTAS "Life cycle analysis of offshore and onshore sited wind power plants based on VesTas V90-3.0 MW turbines." (June 2006)
23 Source: Action Plan for Low Carbon Society Target value of the Federation of Electric Power Companies of Japan
24 It is different from the model publicized by the Japan Carbon Fiber Manufacturers Association. For details of the model, refer to 8. Appendix.

• Annual amount of power generation per unit of wind turbine power generator (MWh) (b)	8,760	8,760
• CO_2 emission relative to annual power generated per unit of wind turbine power generation system (t-CO_2/unit/year) (a)×(b)	(c) 43.8	(d) 2,890.8
• Difference in CO_2 emission relative to annual power generated per unit of wind turbine power generation system (t-CO_2/unit/year) (c) – (d)	▲2,847	–
3) Effect of reduction in CO_2 emission per unit of wind turbine power generation system over its lifetime (t-CO_2/unit/20 years)	▲56,940	–

Table 6. Reduction in CO_2 emission per unit (wind turbine power generation vs. electric power utilities)

[3] Effect of introduction throughout Japan

The effect of reduction in CO_2 emission in 2020 relative to the amount of carbon fiber produced throughout Japan has been calculated.

- Number of units introduced in the year 2020: 150 units
  Amount of carbon fiber used in the year 2020: 450 tons
  According to the national government's prediction for the introduction[25], wind power generation of a maximum of 450 MW per year will be added around 2020. Assuming that 1 unit of wind turbine power generation system has an output of 3 MW, Japanese manufacturers will introduce 150 wind turbines. The amount of carbon fiber used in the wind turbines is estimated to be 450 tons, as each unit uses 3 tons.
- CO_2 emission during the manufacturing stage of chemical products: 9,000 tons
  The net increment of carbon fiber obtained by multiplying the emissions per unit, 60 t-CO_2/unit, by the number of units to be introduced, 150 units.
- Effect of lifetime CO_2 emission reduction of wind turbine power generation to be introduced in 2020: ▲8,540,000 tons
  The effect of reduction in emissions has been estimated by multiplying the number of units to be introduced during the year 2020, 150 units, by the reduction in CO_2 emission over the lifetime per unit, ▲56,940 t-CO_2/unit/20 years.

1) Degree of use in 2020	
• Degree of use in 2020 (MW)	450
• Number of units of wind turbine power generation system in 2020 (units)	150
(Amount of carbon fiber used for the application of wind turbine power generators in 2020) (tons)	(450)
2) CO_2 emission from extraction to the manufacture of carbon fiber (2020)(1,000 t-C	9
3) Effect of lifetime reduction in CO_2 emission (2020, portion of use for 20 years) (1,000 t-CO_2)	▲8,540

Table 7. Effect of reduction in emissions as of 2020

25 Source: Website of the Ministry of Economy, Trade and Industry
http://www.meti.go.jp/committee/summary/0004629/framework.html

4.3 Improvement in fuel economy by weight reduction 1 - automotive materials (carbon fiber)

(1) Overview of carbon fiber as an automotive material[26]

Carbon fiber has various applications as an automotive material. The use of carbon fiber enables weight reduction in automobiles while maintaining strength and safety. Weight reduction in automobiles leads directly to improved fuel economy and helps to reduce CO_2 emission in the transportation sector. This report evaluates the reduction in CO_2 emission due to improved fuel economy through the use of carbon fiber compared with conventional automobiles[27].

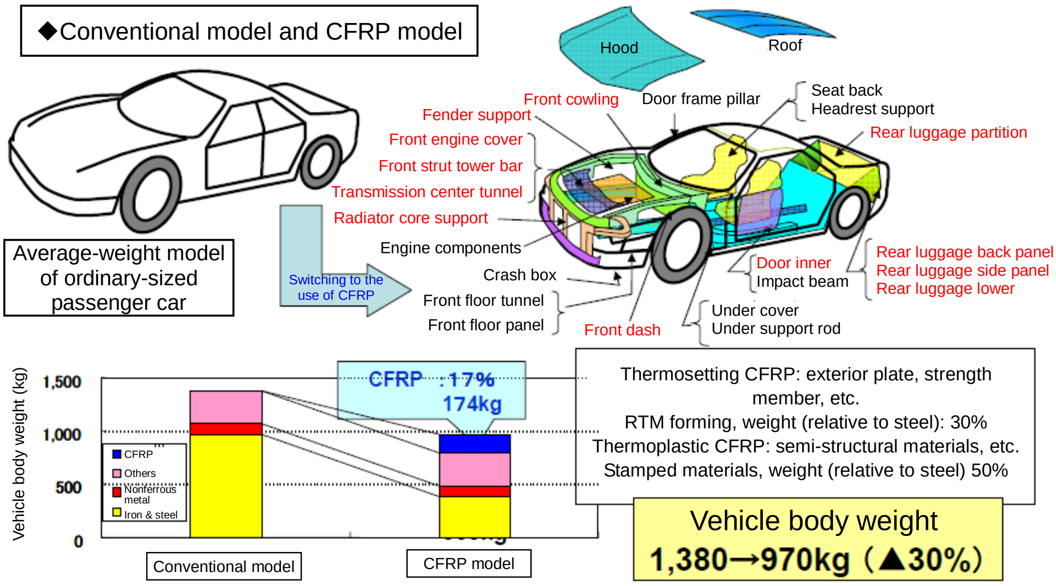

Fig. 23. Carbon fiber for automobiles

[1] Nature of the reduction in CO_2 emission

A reduction in fuel consumption by increasing fuel economy through weight reduction

[2] Examples of chemical products used in automobiles

- Carbon fiber
- Epoxy resin

(2) Analysis conditions

[1] Analysis targets and comparison targets

- Analysis target: Automobiles in which conventional materials have been replaced with carbon fiber (CFRP[28] model)
- Comparison target: Automobiles in which no carbon fiber is used (conventional model)

[2] System boundaries (scope of analysis)

The entire life cycle of an automobile is considered. Namely, analysis was made for the CFRP model and the conventional model at the stage from manufacture of raw materials, through parts manufacture, the assembly of automobiles, product use (driving), and to the disposal of automobiles. Note that, in this evaluation, resins and carbon fiber for automotive use are calculated on the basis of reuse as CFRP by crushing them and adding them at the time of injection molding.

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[26] For an overview of carbon fiber, refer to Section 4.2 "Materials for wind turbine power generation."
[27] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
[28] Carbon Fiber Reinforced Plastics

[3] Criteria for calculating the effect of emission reduction

- Automobiles to be analyzed: Automobiles that run only on gasoline
- Vehicle weight assumed: CFRP model 970 kg/unit
  Conventional model 1,380 kg/unit (average vehicle weight as of 2006)
  → 30% reduction in vehicle weight compared with the conventional model. A total of 174 kg/unit of CFRP is used.
- Fuel economy assumed[29]: CFRP model One liter of gasoline per 12.40 km
  Conventional model One liter of gasoline per 9.83 km
- Vehicle life[30]: Assumed to be 94,000 km over 10 years of use.
- Reduction in CO_2 emission per unit of the CFRP introduced

  One automobile is considered the unit for CFRP introduced. The reduction in CO_2 emission per automobile is calculated as the difference between that over the life of the automobile manufactured using CFRP and that over the life of the conventional automobile (10 years; including driving for 94,000 km and disposal).

(3) Result of analysis[31]

[1] Result of analysis using c-LCA per unit (for 1 unit introduced)

Finished product CO_2 emission from extraction to the automobile manufacture and assembly to disposal Total of the portions indicated in green in Table 8: **6.2 t-CO_2/unit**

Calculation of avoided CO_2 emission

The use of carbon fiber in automobiles results in weight reduction and improved fuel economy. The difference in CO_2 emission due to the reduction in gasoline consumption has thereby been used as the avoided CO_2 emission.

The CO_2 emission from extraction used in automobiles through to assembly and disposal increase by 0.8 tons/unit compared with those in the conventional model. However, during use, the CO_2 emission reduce by about ▲5.4 tons with the CFRP model. avoided CO_2 emission over the entire life cycle is about ▲5 tons/unit▪10 years.

- Avoided CO_2 emission: ▲5 t-CO_2/unit▪10 years

		CFRP model	Conventional model
CO_2 emission in the stages of extraction to the manufacture of materials (t-CO_2/unit)		**5.1**	**3.9**
CO_2 emission during automobile assembly (t-CO_2/unit)		**0.8**	**1.2**
During use	Fuel economy while driving (km/ℓ-gasoline)	12.40	9.83
	Lifetime mileage (km)	94,000	
	Lifetime amount of gasoline used (ℓ)	7,580	9,560
	CO_2 emission coefficient during gasoline combustion[32] (kg-CO_2/ℓ)	2.72	
	CO_2 emission during use (t-CO_2/unit▪10 years)	**20.6**	**26.0**
CO_2 emission in the stages of disposal/recycling (t-CO_2/unit)		**0.3**	**0.3**
CO_2 emission over the entire life cycle (t-CO_2/unit▪10 years)		**26.8**	**31.4**
Lifetime reduction in CO_2 emission (t-CO_2/unit▪10 years)		**▲5**	

Table 8. CO_2 emission over the life cycle of one automobile

[29] Specified based on the material of Japan Automobile Manufacturers Association (material: 2008; track record: 2006)
[30] Specified based on the material of the Ministry of Land, Infrastructure, Transport and Tourism (investigation: March 2008; track record: 2006)
[31] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
[32] Specified based on the values of the Ministry of the Environment, various associations and various automobile manufacturers.

[2] Effect of introduction throughout Japan

The reduction in CO_2 emission in 2020 relative to the amount of carbon fiber produced throughout Japan has been calculated.

- Method of trial calculation for the number of automobiles made using carbon fiber

  The number of automobiles introduced that use carbon fiber has been obtained by estimating the amount of carbon fiber manufactured by manufacturers in Japan for use in automobiles in 2020, and assuming that 100 kg of carbon fiber is used per unit.

  a. Estimated amount of carbon fiber for automotive use by manufacturers in Japan[33]:
  Worldwide 30,000 tons
  Japan 1,500 tons (about 5% of the worldwide total)

  b. Amount of carbon fiber used per unit: 100 kg/unit

  c. Number of units introduced: Worldwide About 300,000 units
  Japan 15,000 units

- CO_2 emission in the stages of extraction/assembly/disposal: 93,000 tons
  (6.2 t-CO_2/unit × 15,000 units)
- Avoided CO_2 emission: ▲75,000 tons/10 years

	Japan	World (for reference)
1) Degree of use in 2020		
• Amount of carbon fiber for automotive use in 2020 (tons)	1,500	30,000
• Number of automobiles introduced that use carbon fiber (1,000 units)	15	300
2) Effect of reduction in CO_2 emission based on this scenario		
• Life cycle avoided CO_2 emission per unit (t-CO_2/unit▪10 years)	▲5	
• Effect of reduction in CO_2 emission for automobiles (that use carbon fiber) in 2020 (1,000 tons-CO_2/10 years)	▲75	▲1,500

Table 9. Effect of reduction in emissions as of 2020

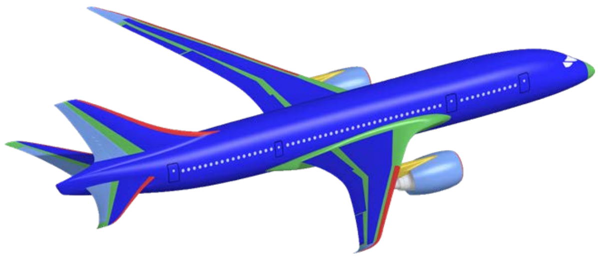
The avoided CO_2 emission obtained through the use of carbon fiber in automobiles produced in Japan can be estimated to be 1.5 million tons in 2020 considering worldwide supply. The portion of the avoided CO_2 emission in Japan becomes 75,000 tons.

4.4 Improvement in fuel economy by weight reduction 2 - aircraft materials (carbon fiber)

(1) Overview of carbon fiber as an aircraft material[34]

Carbon fiber has various applications in aircraft. The use of carbon fiber enables weight reduction in aircraft while maintaining strength and safety. As with automobiles, weight reduction in aircraft leads directly to improved fuel economy and helps to reduce CO_2 emission in the transportation sector. This report evaluates the reduction in CO_2 emission due to improved fuel economy due to the use of carbon fiber compared with conventional aircraft[35].

[33] Estimation by the Japan Carbon Fiber Manufacturers Association
[34] For an overview of carbon fiber, refer to Section 4.2 "Materials for wind turbine power generation."
[35] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/



Using Boeing 767 having a model body structure of the same material composition as Boeing 787

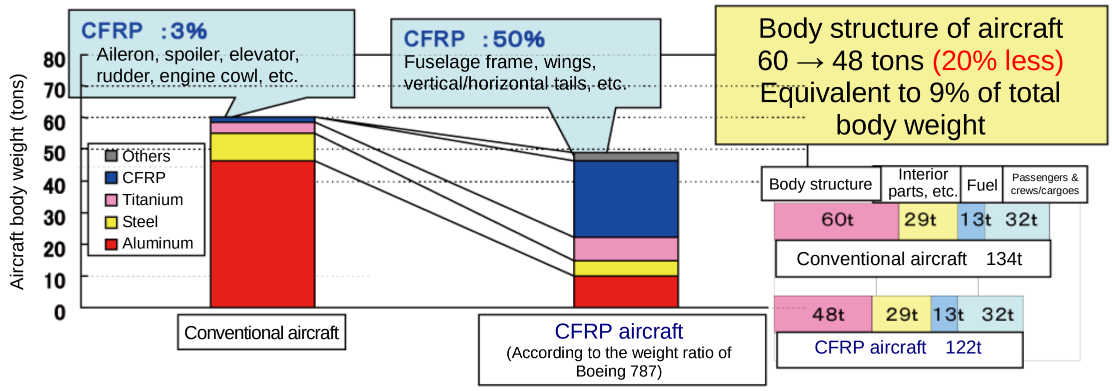


Fig. 24. Carbon fiber for aircraft use

[1] Nature of the reduction in CO_2 emission

A reduction in fuel consumption by increasing fuel economy through weight reduction

[2] Examples of chemical products used in aircraft

- Carbon fiber
- Epoxy resin

(2) Analysis conditions

[1] Analysis targets and comparison targets

- Analysis target: The body of an aircraft that consists of 50% CFRP (CFRP aircraft)
- Comparison target: The body of an aircraft that consists of 3% CFRT (conventional aircraft)

Specifically, the analysis is based on the conventional Boeing 767 (conventional aircraft) and a model aircraft body having the same material composition as the Boeing 787 (CFRP aircraft).

[2] System boundaries (scope of analysis)

The entire life cycle of an aircraft is considered. Namely, analysis was made for the CFRP model and the conventional model at the stages from extraction, through to parts manufacture, aircraft assembly, and product use (flying). Disposal was excluded from the calculations because there is no record of disposal.

[3] Criteria for calculating the effect of emission reduction

- Body weight: Conventional aircraft 60 tons/unit Proportion of CFRP use 3%
  CFRP aircraft 48 tons/unit Proportion of CFRP use 50%
  Reduction of 20% compared with conventional aircraft
- Fuel economy: Conventional aircraft One kiloliter of jet fuel per 103 km
  CFRP aircraft One kiloliter of jet fuel per 110 km
- Lifetime mileage: It is assumed that over 10 years of use, there are 2,000 flights annually between the Haneda Airport and Chitose Airport (500 miles).

- Reduction in CO_2 emission per unit of CFRP introduced

  One aircraft is considered the unit for CFRP introduced. The reduction in CO_2 emission per aircraft is calculated as the difference between that over the entire life of the aircraft manufactured using CFRP and that over the entire life of the conventional aircraft (including 20,000 flights over 10 years, but not including disposal).

(3) Result of analysis[36]

[1] Result of analysis using c-LCA per unit (for 1 unit introduced)

Finished product CO_2 emission from extraction to aircraft manufacture and assembly

Total of the portions in green in Table 10: **3.9 t-CO_2/unit**

Calculation of avoided CO_2 emission

The use of carbon fiber in aircraft results in weight reduction and improved fuel economy. The difference in CO_2 emission due to the reduction in jet fuel consumption has thereby been used as the avoided CO_2 emission.

The CO_2 emission from extraction used in aircraft through to the manufacture of materials increase by 0.2 kt/unit compared with those in the conventional aircraft. However, during assembly, the CO_2 emission reduce by about ▲0.8 kt with the CFRP aircraft, and by about ▲26.3 kt during flight, with the avoided CO_2 emission in the entire life cycle becoming ▲27 kt.

- Avoided CO_2 emission : ▲27k t-CO_2/unit･10 years

		CFRP aircraft	Conventional aircraft
CO_2 emission in the stages of extraction to the manufacture of materials (kt-CO_2/unit)		**0.9**	**0.7**
CO_2 emission during aircraft assembly (kt-CO_2/unit)		**3.0**	**3.8**
During use	Fuel economy during flight (km/kℓ-jet fuel oil)	110	103
	Lifetime mileage (miles)	500 miles × 20,000 flights	
	Lifetime amount of jet fuel used (kℓ/unit)	145,500	155,300
	CO_2 emission coefficient during combustion of jet fuel[37] (kg-CO_2/ℓ)	2.5	
	CO_2 emission during use (kt-CO_2/unit･10 years)	**364**	**390**
CO_2 emission in the stage of disposal (kt-CO_2/unit)		**No Data**	**No Data**
CO_2 emission over the entire life (kt-CO_2/unit･10 years)		**368**	**395**
Effect of lifetime reduction in CO_2 emission (kt-CO_2/unit･10 years)		**▲27**	

Table 10. CO_2 emission in the life cycle of one unit of aircraft

[2] Effect of introduction throughout Japan

The effect of reduction in CO_2 emission in 2020 relative to the amount of carbon fiber produced throughout Japan has been calculated.

- Method of trial calculation for the number of aircraft manufactured that use carbon fiber

  The number of aircraft manufactured that use carbon fiber has been obtained by estimating the amount of carbon fiber manufactured by manufacturers in Japan to be used in aircraft in 2020, and assuming that 20 tons of carbon fiber is used per unit.

[36] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

[37] Specified based on the material of airline companies.

a. Estimated amount of use of carbon fiber for use in aircraft by manufacturers in Japan[38]:

Worldwide 18,000 tons

Japan 900 tons (about 5% of the worldwide total)

b. Amount of carbon fiber used per unit: 20 tons/unit

c. Number of units introduced: Worldwide About 900 units

Japan 45 units

- CO_2 emission in the stages of extraction/assembly: 176,000 tons (3.9k t-CO_2/unit × 45 units)
- Avoided CO_2 emission: ▲1,220,000 tons/10 years

1) Degree of use in 2020	Japan	World (for reference)
• Amount of carbon fiber used in aircraft in 2020 (tons)	900	18,000
• Number of aircraft introduced that use carbon fiber (units)	45	900
2) Effect of reduction in CO_2 emission based on this scenario (kt-CO_2)		
• Life cycle avoided CO_2 emission per unit (kt-CO_2/unit▪10 years)	▲27	
• Effect of reduction in CO_2 emission for aircraft (that uses carbon fiber) in 2020 (1,000 tons-CO_2/10 years)	▲1,220	▲24,300

Table 11. Effect of reduction in emissions as of 2020

Based on this reduction in emissions per ton and the amount of carbon fiber for aircraft use, the avoided CO_2 emission obtained through the use of carbon fiber in aircraft produced in Japan is estimated to be 24.3 million tons in 2020 considering worldwide supply. The portion of abatement in Japan becomes 1,220,000 tons.

38 Estimation by the Japan Carbon Fiber Manufacturers Association

4.5 Conserving energy 1 - LED-related materials

(1) Overview of LED lighting

An LED (light-emitting diode) is a semiconductor (diode) that emits light when an electric current is made to flow through it. A light that uses an LED as its light source is an LED lamp. Together with organic EL lighting, LED lamps are attracting attention as the next generation of energy-efficient lights. It is expected that they will achieve a high level of light-emitting efficiency (lm/W), which is one of the indices of energy conservation. LED lamps will be used in various applications other than lighting, such as the display devices of IT equipment and electronic equipment, and automotive lamps.

[1] Nature of the reduction in CO_2 emission

Long useful life with low power consumption.

[2] Features of the LED lamp

- High light-emitting efficiency (lm/W)

LED lamp	150 lm/W (expected value around 2015[39])
Fluorescent lamp	Around 100 lm/W (at present)
Incandescent light bulb	Around 15 lm/W (at present)

- Small in size, generating a small amount of heat, with a long life
- Superior light-adjusting functions.

  There is the possibility of LED lamps becoming a key technology in energy utilization, becoming incorporated into an energy management system, such as HEMS/BEMS.

[3] Examples of chemical products used in LEDs

- LED packages, chips
- LED printed circuit boards (GaAs, GaP, GaN, SiC, sapphire)
- Organic metals for use in MO-CVD
- LED sealing materials (epoxy, silicone)
- LED resin packages (reflector resins: polyamide based, silicone, liquid crystal polymer)
- LED ceramic packages
- Fluorescent lamps, high heat dissipation printed circuit boards, paint for improving illuminance, etc.

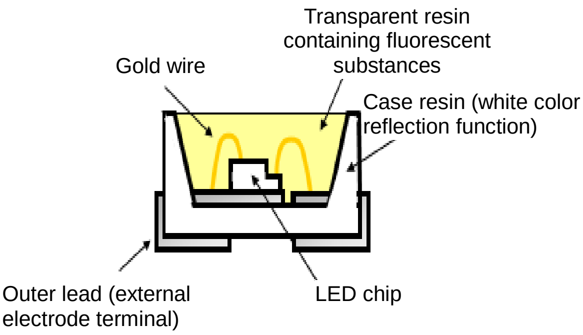



Fig. 25. Appearance and construction of an LED lamp

[39] Source: Japan LED Association "Technical Roadmap of White LEDs" (2008)

(2) Analysis conditions

[1] Analysis targets and comparison targets

With regard to the materials related to LEDs, comprehensive avoided CO_2 emission including that in the manufacture, use and disposal of LED lamps was evaluated by comparing it with that of existing incandescent light bulbs.

- Analysis target: LED lamps
- Comparison target: Incandescent light bulbs

[2] Criteria for calculating the effect of reduction in emission

- Definition of product functions

The product functions are defined as those that provide the same brightness during the same period, and the units that achieve the specified functions with regard to LED lamps and incandescent light bulbs are used as the analysis target. In this analysis, the useful life of an LED product is 25,000 hours, which is 25 times longer than that of an incandescent light bulb. Due to this difference, one LED lamp is taken as equivalent to 25 incandescent light bulbs in this analysis.

		Analysis target LED lamp	Comparison target Incandescent light bulb
Product useful life	(hours)	25,000	1,000
Number of units required to achieve lighting for 25,000 hours	(units)	1	25
Power consumption	(W/unit)	8	40

Table 12. Analysis target (LED lighting) and comparison target (incandescent light bulb) for LED-related materials [40]

- Annual reduction in CO_2 emission per unit degree of use

With one LED lamp having a life of 25,000 hours, which is used as the datum, a comparison of CO_2 emission throughout the entire life cycle has been made with regard to the number of light bulbs that correspond to the datum (one LED lamp or 25 incandescent light bulbs).

[3] System boundaries (scope of analysis)

All processes related to the raw materials extraction for the finished products (light bulbs), product manufacture, use and disposal. Disposal has been specified as noncombustible trash that is disposed of by landfill after intermediate treatment.

(3) Result of analysis

[1] Result of analysis using c-LCA per unit (useful life of an LED lamp: 25,000 hours)

Finished product (LED lamp) CO_2 emission from extraction to manufacture and assembly to disposal

Total of portions indicated in green in Table 13: **3.27 kg-CO_2/25,000 hours**

- Comparison of CO_2 emission from electric power used in the extraction through to manufacture and disposal

Although the power consumption per unit during manufacture is around 16 times greater with LED lamps (LED: 9.9 kWh/unit; incandescent: 0.612 Wh/unit), if the consumption is converted to that per unit useful life of the product (25,000 hours), the subtotal value is smaller with LED lamps.

[40] Source: OSRAM "Life Cycle Analysis of Illuminants: A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps" (December 2009)

Calculation of avoided CO_2 emission

- Comparison of power consumption during use

  Since each LED lamp uses less power (LED: 8 W/unit; incandescent: 40 W/unit) and since one LED lamp lasts 25 times longer than an incandescent lamp (LED: 25,000 hours; incandescent: 1,000 hours), the reduction of power consumption during use results in a significant reduction in CO_2 emission.

- Avoided CO_2 emission: ▲266 kg-CO_2/25,000 hours

  The reduction in CO_2 emission over the entire life cycle of an LED lamp becomes ▲266 kg-CO_2/25,000 hours, which is calculated as the difference from that of an incandescent light bulb.

Process being analyzed	LED light bulb	Incandescent light bulb
[1] From the extraction to manufacture/assembly		
Power consumption from the extraction to manufacture/assembly (kWh/unit)	9.9	0.612
Number of units manufactured corresponding to the useful life of an LED product (units)	1	25
CO_2 emission coefficient of electric power[41] (kg-CO_2/kWh)	0.33	0.33
Subtotal: CO_2 emission related to the extraction to manufacture (kg-CO_2)	**3.27**	**5.05**
[2] During use		
Power consumption during use for 25,000 hours (kWh)	200	1,000
CO_2 emission coefficient from electric power (kg-CO_2/kWh)	0.33	0.33
Subtotal: CO_2 emission related to use (kg-CO_2)	**66**	**330**
[3] Landfill		
Number of units disposed of by landfill (units)	1	25
CO_2 emission related to landfill (kg-CO_2/unit)	0.002	0.009
Subtotal: CO_2 emission related to disposal (kg-CO_2)	**0.002**	**0.225**
CO_2 emission through the entire life cycle (kg-CO_2) (Total of [1] to [3])	**69.272**	**335.275**
Reduction in emissions (kg-CO_2/25,000 hours)	**▲266**	

Table 13. Result of analysis of LED lamps[42]

[2] Effect of introduction throughout Japan

The reduction in CO_2 emission in 2020 relative to the degree of use throughout Japan has been calculated.

- Expected amount of annual sale of LED light bulbs in 2020[43]: 28 million units
- CO_2 emission in the stages of extraction/manufacture/landfill of LED products: 92,000 tons
- Avoided CO_2 emission: ▲7.45 million tons

41 Electric power emission factor (power receiving end) in FY 2020: Target value of the Federation of Electric Power Companies of Japan

42 Source: OSRAM "Life Cycle Analysis of Illuminants: A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps" (December 2009)

43 Source: Fuji Chimera Research Institute "General Investigation of LED Related Markets in 2010 (first volume)"

4.6 Conserving energy 2 - thermal insulation materials for housing

(1) Overview of thermal insulation materials for housing

In a domestic household, cooling and particularly heating account for the largest portion of energy consumption. To make optimum use of the energy consumed by cooling and heating, it is necessary that the thermal insulation and air tightness of each house to be improved. This is because heat flows in and out through the walls, ceilings, roof, floor, windows and entrances if there is a difference between the internal and external temperatures, even if the temperature inside is comfortable through the use of cooling or heating. To prevent the transfer of heat, the thermal insulation in housing can be improved by covering the inside of a room with insulation materials as though it was being wrapped up.

[1] Nature of the reduction in CO_2 emission

A reduction in the power used for cooling and heating through the use of thermal insulation

[2] Types of thermal insulation materials for housing currently used

- Those that use rock wool, glass wool, etc.
- Those that use resin materials, including mainly polystyrene and urethane

  In this analysis, a comparison has been made between housing that is thermally insulated and housing that is not thermally insulated, with polystyrene foam made from beads used as the analysis target. The difference in CO_2 emission between glass wool and resin materials is small in terms of LCA. (Although thicker units of glass wool are used during construction work as compared with resin materials to obtain the same level of thermal insulation, the emissions from glass wool during manufacture are small.) Also, the shipped volume of polystyrene foam made from beads, which is a resin material, is greater in Japan.

[3] Features of polystyrene foam made from beads[44]

- Typical foamed plastic-based thermal insulation materials that were developed in Germany
- The materials are called EPS, which is an acronym for "expanded poly-styrene."

  Manufacturing method: The beads (raw material) consisting of polystyrene resins and hydrocarbon-based foaming agents are subjected to preparatory foaming. They are then foamed to about 30 to 80 times by filling them into molds and heating them. Various shapes of products can be manufactured by changing the shape of the mold.

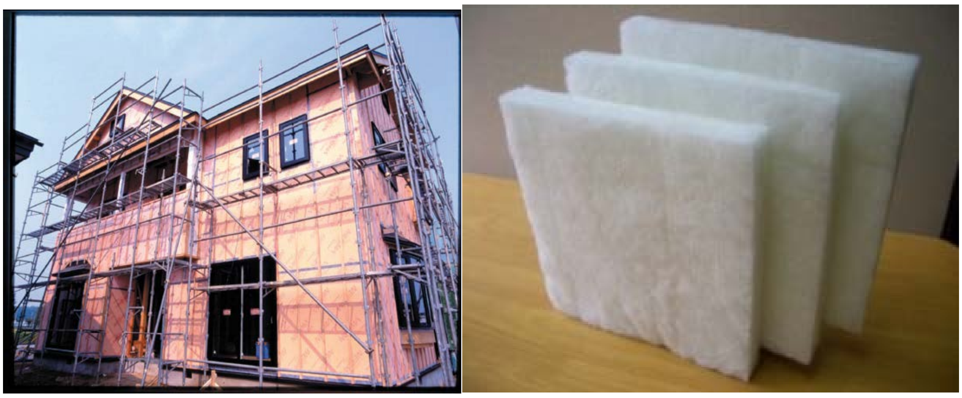


Fig. 26. Thermal insulation materials

[4] Examples of chemical products used as thermal insulation materials

- Extruded polystyrene foam, polystyrene foam made from beads
- Hard urethane foam, urethane resin, propylene oxide
- Highly expanded polystyrene foam, phenol foam
- PVC sash, PVC resin
- Heat-shielding paint, heat-shielding sheets, heat-shielding film, high thermal insulation curtains, nonwoven fabric, alumina fiber

44 Source: "Overview of EPS Construction Materials" in the website of the Japan Expanded Polystyrene Association, EPS Construction Materials Promotion Department http://www.epskenzai.gr.jp/what/what01.html

(2) Analysis conditions

[1] Analysis targets and comparison targets

With polystyrene foam made by from beads being used as the analysis target, the analysis has been made where foam is introduced into freestanding houses and apartments.

- Analysis target: Housing that uses thermal insulation
- Comparison target: Housing that does not use thermal insulation

[2] Criteria for calculating the effect of emission reduction

- Product functions:

  Analysis concerned housing that can attain the conditions of a certain space and certain atmospheric temperature, etc. during a certain period of time. The cold air and warm air generated by air conditioners and heating devices are more likely to be lost if no thermal insulation is used, thereby consuming considerable electricity and fuel to compensate for the loss of cold air or warm air.

  In this analysis, the effect of thermal insulation materials has been compared for the same housing, with contents that meet certain conditions, such as atmospheric temperature.

- Number of years that the housing is used[45]: Free-standing houses 30 years
  Apartments 60 years

  The evaluation assumes that the housing will be used for the same number of years, irrespective of whether thermal insulation is used.

- Annual reduction in CO_2 emission per unit degree of use

  The difference between the CO_2 emission in housing that uses thermal insulation and those of housing that does not use insulation has been determined. The unit degree of use has been set at the emission reduction per freestanding houses and per apartment. Since the energy used for cooling and heating housing varies greatly in each region of Japan, the calculations have been made by dividing Japan into five regions from Hokkaido to Kyushu.

[3] System boundaries (scope of analysis)

- Processes to be analyzed for housing that uses thermal insulation
  a. Processes related to the extraction through to the manufacture and disposal of the thermal insulation. Disposal has been specified as consisting of incineration.
  b. Processes of use of housing (mainly air conditioning)
- Processes to be analyzed for housing that does not use thermal insulation
  a. Processes of use of housing only (mainly air conditioning)
- Processes not analyzed
  a. The construction of the housing itself
  b. Energy consumption other than that of air conditioning (such as gas cookers)

  These are considered to be processes that do not affect the entire processes for which there are insignificant differences in CO_2 emission in the same process, irrespective of whether thermal insulation is used.

[45] Source: Japan Expanded Polystyrene Recycling Association "EPS Product Environmental Load (LCI) Analysis and Investigation Report" (April 2007)

(3) Result of analysis

[1] Result of analysis using c-LCA per unit (one house)

Chemical product CO_2 emission from extraction to manufacture and disposal

Total of the portions indicated in blue in Tables 14 and 15:

Extraction - manufacture - disposal of thermal insulation materials:

Freestanding houses Average **3,505 kg-CO_2/residence**

Apartments Average **1,677 kg-CO_2/residence**

Calculation of avoided CO_2 emission

The use of thermal insulation causes an increase in CO_2 emission when the materials are manufactured, but there is a greater reduction in CO_2 emission when the insulated housing is used. There is a regional difference in the effect of emission reduction[46] in each residence at the end of its life (freestanding houses: 30 years; apartments: 60 years). The reduction is 9 tons - 45 tons/residence in the case of freestanding houses, or about 26 tons/residence on average, and 44 tons - 170 tons/residence in the case of apartments, or about 105 tons/residence on average.

- Avoided CO_2 emission: Freestanding houses Average ▲25,975 kg-CO_2/residence
  Apartments Average ▲104,705 kg-CO_2/residence

Region	CO_2 emission during the extraction to the manufacture of thermal insulation	CO_2 emission reduction during use of the housing	CO_2 emission during disposal of thermal insulation	Total
Sapporo	2,295	▲49,443	2,412	▲44,736
Morioka	1,687	▲40,564	1,773	▲37,104
Sendai	1,520	▲28,613	1,598	▲25,495
Tokyo	1,520	▲16,642	1,598	▲13,524
Kagoshima	1,520	▲12,140	1,598	▲9,022
Average	**1,709**	▲29,480	**1,796**	▲25,975

Table 14. Result of calculation per residence for freestanding houses (unit: kg-CO_2/residence▪30 years)

Region	CO_2 emission during the extraction to the manufacture of thermal insulation	CO_2 emission reduction during use of the housing	CO_2 emission during disposal of thermal insulation	Total
Sapporo	1,145	▲173,405	1,204	▲171,056
Morioka	855	▲146,661	899	▲144,908
Sendai	714	▲100,622	751	▲99,157
Tokyo	687	▲65,361	722	▲63,952
Kagoshima	687	▲45,861	722	▲44,452
Average	**818**	▲106,382	**859**	▲104,705

Table 15. Result of calculation per residence for apartments (unit: kg-CO_2/residence▪60 years)

[46] Source: Japan Expanded Polystyrene Recycling Association "EPS Product Environmental Load (LCI) Analysis and Investigation Report" (April 2007)

[2] Effect of reduced emissions throughout Japan

Based on the average analysis of a house as stated above, the reduction in emissions considering the end of the life of houses that are built in 2020 has been determined by multiplying the result by the number of freestanding houses/apartments to be built in 2020.

- Number of residences in which thermal insulation materials will be introduced in 2020[47]: 1 million residences
- Ratio of freestanding houses/apartments[48]: Freestanding houses 36.7% (367,000 residences)
  Apartments 63.3% (633,000 residences)
  * Method of calculation: Calculated from the ratio of the number of apartments in a housing development project to the number of freestanding houses to be built
- CO_2 emission in the stages of manufacture/disposal of thermal insulation materials: 2.35 million tons
- CO_2 emission from all the freestanding houses and apartments that use thermal insulation materials to be built in 2020: ▲76 million tons

[1] Number of residences that will use thermal insulation in 2020	
• Freestanding houses	367,000
• Apartments	633,000
[2] Effect of reduction in CO_2 emission per residence through the introduction of thermal insulation	
• Freestanding houses (effect over 30 years) (t-CO_2/residence)	▲26
• Apartments (effect over 60 years) (t-CO_2/residence)	▲105
[3] Effect of reduction in CO_2 emission based on the scenario in which the materials are introduced	
• Freestanding houses (effect over 30 years) (1,000 t-CO_2)	▲9,500
• Apartments (effect over 60 years) (1,000 t-CO_2)	▲66,500
Total (1,000 t-CO_2)	▲76,000

Table 16. Effect of reduction in emissions as of 2020

4.7 Conserving energy 3 - Hall effect devices and Hall effect ICs

(1) Overview of DC brushless motors

A DC brushless motor is a direct current motor that does not have a commutator. It has the advantages of superior efficiency (power conservation) compared with an AC motor (induction motor). Conventionally, AC motors having poor energy efficiency were used for the fans of indoor and outdoor units, but in Japan, where there are stringent regulations on the conservation of energy, DC brushless motors are currently used.

In a DC brushless motor, the position of the rotor is detected by means of a Hall effect device or Hall effect IC to change the polarity. The polarity of the motive power is changed by providing feedback to the control circuit by means of a signal that indicates the rotor position.

[1] Nature of the reduction in CO_2 emission

Reduced power consumption through increased efficiency

47 Source: Specified based on the "2009 Edition Thermal Insulation Materials Market White Paper" of Yano Research Institute.
48 Source: Ministry of Land, Infrastructure and Transport "Construction Statistics Annual Report" (2006)

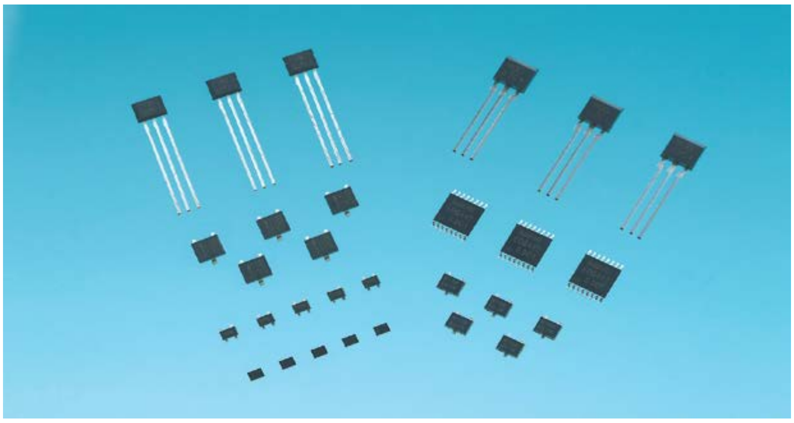
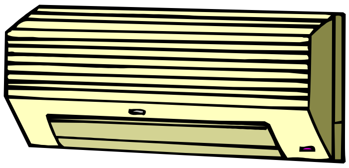
 

Fig. 27. Hall effect device, Hall effect IC, and air conditioner

(2) Analysis conditions

[1] Analysis target and comparison target

- Analysis target: DC brushless motors
- Comparison target: AC motors that use the same alternating current power supply

[2] Criteria for calculating the effect of emission reduction

- Product functions: Both products must provide the same motor output during the same period. There must be no difference between the two.
- Annual electrical energy consumption per unit (kWh/unit):

  The consumption has been calculated after calculating the input W by dividing the output W of each of the indoor and outdoor units by the efficiency (%) specified for the DC brushless motor and the AC motor, by multiplying the input W thus obtained by the annual number of hours of operation.
- Product life: 8 years (the two products have the same life)

	Analysis target DC brushless motor	Comparison target AC motor
Product life (years)	8	
Annual number of hours of operation (hours/unit)	2,000	
Functional unit	• Motor output of the external unit of an air conditioner: 70 (W/unit▪air conditioner) • Motor output of the indoor unit of an air conditioner: 60 (W/unit▪air conditioner)	
Efficiency (%)	80	40
Electricity consumption (kWh/unit)	325	650

Table 17. Analysis target for the Hall effect IC (DC brushless motor) and comparison target (AC motor)[49]

- Annual reduction in CO_2 emission per unit of degree of use

  It has been decided to obtain the reduction in CO_2 emission by assuming that a DC brushless motor produced in a certain year will be put into continuous operation until the end of its life. In other words, the reduction produced by a product manufactured in a certain year will reduce emissions into the future, but the reduction will be regarded as the reduction in emissions in the given year.

[49] Data provided by Asahi Kasei Corporation

[3] System boundaries (scope of analysis)

The processes analyzed here are only processes related to the manufacture and use of Hall effect devices and IC products.

The processes related to the raw and other materials, transportation, manufacture and the disposal/recycling of finished air conditioner products as well as those related to the manufacture of capital goods do not cause a difference due to the use or non-use of a device. Therefore, these processes are excluded from the analysis target. In particular, there are various ways of disposing of domestic air conditioners according to the methods specified in the Home Appliance Recycling Law, so it is difficult to make any calculations under the present circumstances.

(3) Result of analysis

[1] Result of analysis using c-LCA per unit (for one air conditioner)

Chemical product CO_2 emission from extraction to manufacture portion indicated in blue in Table 18: **<< 1 kg-CO_2/unit**

It is assumed that a DC brushless motor consists of a Hall effect IC incorporated into an AC motor. Hence, it is assumed that the CO_2 emission during the manufacture of the DC brushless motor are equal to the CO_2 emission during the manufacture of the AC motor plus the CO_2 emission during the manufacture of the Hall effect IC. The CO_2 emission related to the manufacture of the Hall effect IC are extremely small, and the difference in CO_2 emission related to the manufacture of motors is excluded from the calculation target.

Calculation of avoided CO_2 emission

Since the power consumed by a DC motor is half the power consumption by an AC motor, the reduction in CO_2 emission over the entire life cycle is substantial.

- Avoided CO_2 emission: ▲858 kg-CO_2/unit

Process subject to analysis	DC brushless motor	AC motor
[1] Processes related to the extraction to manufacture		
CO_2 emission related to the extraction to the manufacture of Hall effect devices (kg-CO_2 /unit)	<<1	–
CO_2 emission related to the extraction to the manufacture of Hall effect ICs (kg-CO_2 /unit)	<<1	–
Subtotal: CO_2 emission related to manufacture (kg-CO_2 /unit)	**<<1**	–
[2] Processes related to power consumption during use		
Annual electricity consumption (2,000 hours) (kWh /year/unit)	325	650
Number of years of operation (years)	8	8
Total electricity over the number of years of operation (kWh /unit)	2,600	5,200
CO_2 emission coefficient of electric power[50] (kg-CO_2/kWh)	0.33	0.33
Subtotal: CO_2 emission related to use (kg-CO_2 /unit)	**858**	**1,716**
CO_2 emission over the entire life cycle (Total of [1] and [2]) (kg-CO_2/unit)	**858**	**1,716**
Reduction in CO_2 emission (kg-CO_2 /unit)	**▲858**	

Table 18. Result of analysis of DC brushless motors[51]

50 Electric power emission factor (power receiving end) in FY 2020: Target value of the Federation of Electric Power Companies of Japan

51 Data provided by Asahi Kasei Corporation (excluding the CO_2 emission of electric power)

[2] Effect of introduction throughout Japan

The global demand for air conditioners in 2020 is expected to be about 100 million units[52]. Assuming that these have devices have a DC motor and that the reduction in CO_2 emission per air conditioner unit is equal to the value mentioned above, there will be a reduction of 85.8 million tons.

It is predicted that the number of air conditioners in demand in Japan in 2020 will correspond to the levels in 2010. Assuming that these devices have a DC motor, the reduction in CO_2 emission in Japan has been calculated.

- Annual number of air conditioners sold in 2020: 7,460,000 units/year
- Avoided CO_2 emission: ▲6.4 million tons

4.8 Conserving energy 4 - piping materials

(1) Overview of polymer piping materials

Polymer piping materials include polyvinyl chloride piping, polyethylene piping and polybutene piping. Together with metal piping materials (carbon steel pipes, zinc-plated steel pipes, resin-coated steel pipes, stainless-steel pipes, copper pipes, aluminum pipes, cast-iron pipes and lead pipes), polymer pipes are widely used in water supply piping (water distribution piping, water supply piping, drainage piping) and gas piping (low-pressure conduit piping) [53].

The features common to polymer piping materials are that they have high flexibility and superior anti-seismic performance. However, since they are degraded by sunlight, they are mainly put to use underground and indoors.

Polyvinyl chloride piping has superior anti-corrosiveness, so it is widely used in drainage equipment and as sewerage piping inside housing. In addition, it is widely used in water supply piping from waterworks as well, together with ductile cast-iron piping.

Polyvinyl chloride piping is widely used in water supply and sewerage, whereas polyethylene piping is used in gas supply. Polyethylene piping has the features of high anti-seismicity partly because its joint can be fused (by electrofusion joining), and is suitable as a gas piping material in Japan, which is prone to earthquakes.

Aside from the above, familiar polymer piping materials include polyethylene piping and polybutene piping, which are used as piping for hot water.

Fig. 28. Polymer pipes

[52] Source: Fuji Chimera Research Institute "General Investigation of Worldwide Electronics Markets in 2009 - Market Analysis and Trend in Future of AV, Home Electric Appliances, Information/Telecommunications Equipment, Electronic Units" (2009)

[53] Source: "Plastic Piping Materials Recent Trends" (Website of "Building Construction, Civil Engineering, and Plant Equipment of Mitsubishi Chemical/Mitsubishi Resin Group" Topic posted on August 27, 2008)(http://www.construction-biz.com/topics/topics080827.html)

[1] Nature of the reduction in CO_2 emission

Energy consumption is reduced consumed because high temperatures are not used during manufacture.

[2] Chemical products used as piping materials

- Polyvinyl chloride (EDC, monomer, polymer)
- High-density polyethylene
- Polybutene

(2) Analysis conditions

The reduction in CO_2 emission was analyzed with regard to polyvinyl chloride piping, for which data for manufacturing the pipes is available.

In general, ductile cast iron piping has a greater strength than polyvinyl chloride piping and in applications requiring strength greater than or equal to a certain level, safety is given priority as a matter of course. However, in this analysis, the weight of a product and the useful life of the product have been used as the preconditions for analysis, and strength and safety have not been incorporated into the analysis.

For this reason, the substitution of polyvinyl chloride piping in all piping applications has not been anticipated. The volume of polyvinyl chloride piping produced in 2020 has been evaluated conservatively with regard to the forecast demand, considering the fact that there may be some applications in which substitution is not possible. The volume has been assumed to be the same as the value forecast for FY 2005.

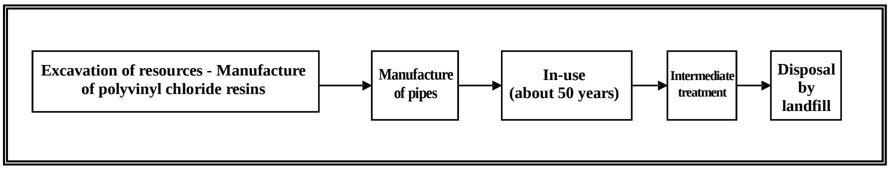
[1] Analysis target and comparison target

- Analysis target: Polyvinyl chloride piping
- Comparison target: Ductile cast iron piping

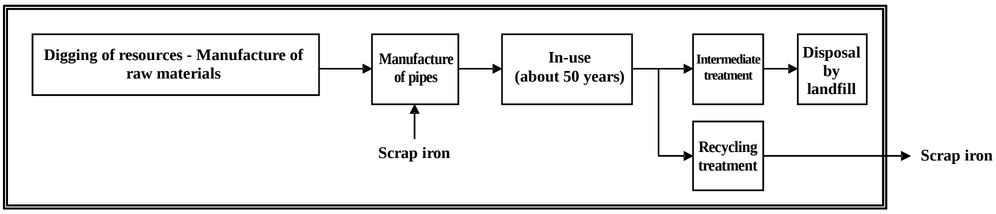
[2] System boundaries (scope of analysis)

The processes subject to this analysis relate to the procurement of the raw materials (from the excavation of resources to the manufacture of unprocessed materials), production (processing) of products, and the disposal of products (specified as disposal by landfill after intermediate treatment of the entire quantity). Processes related to the stage of the use of products and the transportation of products have been excluded from the scope of analysis.

Life cycle flow of pipes made of polyvinyl chloride



Life cycle flow of pipes made of ductile cast iron



Note 1: The double line shows the system boundary (scope of evaluation)
Note 2: According to one source, about 90% of the raw materials used in ductile cast iron piping are scrap iron.

Fig. 29. System boundaries for piping

[3] Criteria for calculating the effect of emission reduction

- Reduction in the emission of CO_2 emission per unit degree of use

  There are differences in the specific gravity as well as the assumed product life between polyvinyl chloride piping and ductile cast iron piping. Corrections have been made for these differences.

(3) Result of analysis

[1] Result of analysis using c-LCA per unit (1 kg of polyvinyl chloride piping)

Finished product (PVC piping) CO_2 emission from extraction to manufacture, assembly and disposal

Total of the portions in green in Table 18: **1.5 kg-CO_2/kg**

Calculation of avoided CO_2 emission

Examples of analysis using the literature[54] are shown below with regard to CO_2 emission of 1 kg of polyvinyl chloride piping and the CO_2 emission of 1 kg of ductile cast iron piping over the respective life cycles.

	Vinyl chloride piping	Ductile cast iron piping
Procurement of raw materials (excavation of resources to the manufacture of unprocessed materials) (kg-CO_2/kg)	1.4	0.146
Production (processing) of products (kg-CO_2/kg)	0.1	1.925
Disposal of products (landfill) (kg-CO_2/kg)	0.018	0.018
Total (kg-CO_2/kg)	**1.5**	**2.1**

Table 18. CO_2 emission per unit of weight over the product life

	Polyvinyl chloride piping	Ductile cast iron piping
Weight per 150 mm diameter and per meter (kg)	6.7	23.8
Assumed life (years)	50	45
Amount equivalent to 1 kg of polyvinyl chloride piping (kg)	1.0	3.95
CO_2 emission (kg-CO_2/kg)	**1.5**	**8.2**
Effect of emission reduction (kg-CO_2/kg)	**▲6.7**	–

Table 19. Effect of reduction in CO_2 emission per kg of polyvinyl chloride piping over its life

After making corrections using the weight and useful life that correspond to one meter of product, reduction in CO_2 emission over the product life cycle of ▲6.7 kg-CO_2 /kg.

- Avoided CO_2 emission: ▲6.7 kg-CO_2 /kg

54 Source: Japan PVC Environmental Affairs Council, Investigational Committee "Life Cycle Analysis of Polyvinyl Chloride Resin Products" (June 1995)

[2] Effect of emission reduction throughout Japan

The reduction in emissions is calculated assuming that the volume of polyvinyl chloride pipes produced in 2020 is the same as that in FY 2005[55].

The reduction in CO_2 emission due to the substitution for ductile cast iron piping having equivalent properties is 3.03 million tons.

In addition, by adding the effect of material substitution for the joints used as pipe connections, the reduction in CO_2 emission becomes 3.3 million tons.

	PVC piping	PVC joints	Total
Assumed production volume in 2020 (tons) (Assuming that it is equivalent to the value for FY 2005)	452,878	40,214	493,092
Reduction in CO_2 emission over the entire life cycle (1,000 tons)	**3,030**	**270**	**3,300**

Table 20. Reduction of CO_2 emission by substituting polyvinyl chloride piping for ductile cast iron piping

- CO_2 emission at the stages of manufacture/disposal of PVC piping: 0.74 million tons
- Avoided CO_2 emission: ▲3.3 million tons

4.9 Conserving energy 5 - materials for seawater desalination plant (RO membranes)

(1) Overview of RO membranes and seawater desalination plants

RO membranes (Reverse Osmosis membranes) are semi-permeable membranes whose properties prevent impurities in water, such as ions and salts, from permeating at a molecular level. These membranes are able to separate fresh water from salts and other impurities.

Permeation is a phenomenon in which solvents transfer from diluted solution to thick solution via a semi-permeable membrane. The difference in pressure that occurs between the two liquids when the action of permeation has ceased and balance has been achieved is called the osmotic pressure. Reverse osmosis is a phenomenon in which the solvent transfers from the thick solution to the diluted solution by applying a pressure greater than the osmotic pressure. By utilizing this principle, it is possible to apply pressure to a solution containing substances to be removed, such as salts (seawater, etc.) thereby obtaining fresh water by allowing only water to permeate through the reverse osmosis membrane. This phenomenon is utilized in seawater desalination technology.

Fig. 30. RO membranes

[55]Source: Website of the Japan PVC Pipe and Fittings Association   http://ppfa.gr.jp

[1] Nature of the reduction in CO_2 emission

A small amount of energy is consumed because no heating is required.

[2] Types of seawater desalination plants

- Evaporation method: Creating distilled water by evaporating seawater
- Membrane method: Removing salt content by means of RO membranes

[3] Trend amongst seawater desalination plants

Seawater desalination that uses the evaporation method was previously the mainstream method. However, the membrane method consumes a small amount of energy and it has become the most common method adopted in large-scale plants.

Considering the international increase in demand for fresh water, the trend toward increased demand for larger seawater desalination plants will continue. As the membrane method uses less energy, it is able to process large volumes of water with small running costs. And as it is environmentally superior, having smaller CO_2 emission, it is expected that the membrane method will become further entrenched as the major alternative.

(2) Analysis conditions

[1] Analysis target and comparison target

- Analysis target: Seawater desalination plant using RO membranes
- Comparison target: Seawater desalination plant using evaporation

[2] Criteria for calculating the effect of emission reduction[56]

- Reduction in CO_2 emission per unit degree of use
  One RO membrane element can process 26,000 cubic meters of seawater, and this figure is used as the datum. The comparison involves the CO_2 emission that result when a desalination plant that uses the evaporation method processes 26,000 cubic meters of seawater.
- Useful life of RO membranes: trial calculation has been made assuming that the life is five years (actual situation: 5 - 7 years)

[3] System boundaries (scope of analysis)

In both the analysis target and the comparison target, the processes related to the manufacture of materials, plant construction, and use of seawater desalination plants are included in the scope of analysis.

Regarding disposal, to evaluate CO_2 emission due to the use of RO membranes, it has been assumed that RO membrane elements will be disposed of by landfill as industrial waste. Also, processes related to the disposal of materials constituting the plant other than the RO membrane elements and transportation processes are not included in the scope of analysis as the corresponding CO_2 emission are negligible.

(3) Result of analysis

[1] Result of analysis using c-LCA per unit (for one RO membrane element for one unit of degree of use)

Finished product (RO membrane desalination plant)

CO_2 emission from extraction to manufacture, construction and disposal

Total of the portions indicated in green in Table 21:

2.46 tons-CO_2/unit (Volume of water processed: 26,000 m^3)

56 Data provided by Toray Industries, Inc. Estimation in FY 2010

Calculation of avoided CO_2 emission

The CO_2 emission of a seawater desalination plant over the life of an RO membrane to process 26,000 m^3 of seawater come to 530 tons. Compared with the CO_2 emission of the comparison target (a desalination plant processing 26,000 m^3 of seawater using the evaporation method), 335.9 tons, one RO membrane reduces emissions by ▲282.9 tons.

- Avoided CO_2 emission: ▲282.9 tons-CO_2/unit (volume of seawater processed: 26,000 m^3)

Unit: tons-CO_2/volume of seawater processed: 26,000 m^3 (per RO membrane unit)		Analysis target	Comparison target
Manufacture of raw materials Manufacture of plant	Manufacture of RO membrane elements	0.01	–
	Manufacture of raw materials for RO membrane elements	0.1	–
	Manufacture of raw materials other than RO membrane elements, plant construction	2.2	12.4
Use		50.5	323.5
Disposal	Waste disposal of RO membrane elements	0.15	–
	Plant dismantling Disposal of raw material other than RO membrane elements	(Beyond the scope of analysis)	
Total	**(tons-CO_2/volume of seawater processed: 26,000 m^3)**	52.96	335.9
Reduction in CO_2 emission	**(tons-CO_2/volume of seawater processed: 26,000 m^3)**	**▲282.9**	

Table 21. Reduction in CO_2 emission per unit degree of use of materials of seawater desalination plants (RO membranes)[57]

[2] Effect of introduction throughout the world

Since there are few seawater desalination plants in Japan and most of the plants are constructed overseas, the evaluation has been made based on the **introduction of RO membranes throughout the whole world**.

Also, because there is no objective data concerning the degree of use in 2020, the material data[58] on the degree of use[59] in 2016, which most closely resembles the data for 2020, has been used as the data for 2020.

- RO membrane desalination capacity to be constructed worldwide in 2016: About 8.7 million m^3/day
- Volume of water processed per RO membrane over its life:
  8.7 million m^3/day × 365 days × 5 years = 15,877,500,000 m^3
- Number of RO membrane elements required:
  15,877,500,000 m^3 ÷ 26,000 m^3 = 610,000 units
- CO_2 emission at the stages of manufacture/disposal of RO membrane elements: 1.5 million tons
- Avoided CO_2 emission (2020, worldwide): ▲ About 170 million tons

[57] Data provided by Toray Industries, Inc. Estimation in FY 2010

[58] Source: Desalination Markets 2010,P54

[59] Source: Report of Round-table Conference on Industrial Competitiveness "Technology for Effective Utilization of Water Treatment and Water Resources [Approach to the Rapidly Expanding Water Treatment Market in the World]" (March 18, 2008)

5. Conclusions and proposals

5.1 Summary of examples of analysis

Of the nine examples analyzed this time by using c-LCA, eight examples of CO_2 emission reductions in Japan are shown in Table 22.

Example	CO_2 emission from extraction through manufacture to disposal of chemical products (1,000 tons)	Production amount (FY 2020)	Avoided CO_2 emission (1,000 tons)	Useful life (years)	Materials for comparison, etc.
Materials for solar power generation	1,290	1,760,000 kW	▲8,980	20	Power source mix
CFRP wind turbine power generation	9	150 units	▲8,540	20	Power source mix
CFRP vehicle	93	15,000 units	▲75	10	Automobile made of iron
CFRP aircraft	176	45 units	▲1,220	10	Aircraft made of aluminum
LED-related materials	92	28,000,000 units	▲7,450	10	Incandescent light bulb
Thermal insulation materials for building construction (freestanding houses)	1,290	367,000 houses	▲9,500	30	Not thermally insulated
Thermal insulation materials for building construction (apartments)	1,060	633,000 houses	▲66,500	60	Not thermally insulated
Hall effect device/IC for DC motors	<<1	7,460,000 units (number of air conditioners)	▲6,400	8	AC motor
Piping materials (*1)	740	493,092 tons	▲3,300	50	Ductile cast iron piping
Total	**4,750**		**▲111,965**		

*1: Difference in emissions during extraction - manufacture - disposal rather than in-use difference

Table 22. Summary of examples of analysis

Reference value for the global effect

Seawater desalination	1,500	610,000 units	▲170,000	5	Evaporation method

5.2 Conclusions and proposals

It can be inferred that chemical products contribute to the realization of CO_2 emission reductions in finished products in various fields such as the energy sector (solar power generation, wind turbine power generation), consumer and home sector (LED lamps, housing, air conditioning, piping), transportation sector (automobiles, aircraft), etc., in cooperation with products that are related to other unprocessed materials and parts.

It can be seen that, based on eight of nine examples dealt with in this report, excluding seawater desalination, chemical products are a key material that contribute to a reduction of about 110 million tons on a finished-product basis, whereas the CO_2 emission from the chemical products themselves account for about 4.75 million tons. This means a reduction effect equivalent to about one-twelfth of the CO_2 emission for all of Japan in 2007, which was about 1.3 billion tons, can be expected.

Note that the avoided CO_2 emission includes that of chemical products as well as other products related to raw materials and parts. However, since no means are currently available for quantifying that of other products, avoided CO_2 emission has not been apportioned to each constituent product.

Based on the foregoing, it is clear that the chemical industry has the status of a basic industry that supports industries through the supply of raw materials and parts, and also is an industry that contributes to society through a reduction in CO_2 emission in present times where the environment has become a pressing problem for human beings.

For this reason, to promote a reduction in CO_2 emission, which is a global problem, it is important to take measures to achieve total optimization based on a full understanding of the life cycle of products, instead of considering partial optimization, such as measures to reduce CO_2 emission during manufacture. From now, the chemical industry is committed to helping to reduce CO_2 emission in society as a whole, aiming at reducing emissions by using chemical technologies and products through their entire life cycle, without being limited to striving to reduce emissions only during manufacture.

6. The chemical industry's plans for the future

6.1 Increasing the number of examples of analysis using c-LCA in Japan

The implementation of c-LCA with the nine examples herein is very significant in that it demonstrates the magnitude of the chemical industry's contribution to avoided CO_2 emission in Japan. However, low-carbon final products in which chemical products help to reduce CO_2 emission are not limited to the nine examples herein. This can be understood from the fact that the total emissions of the chemical industry in FY 2007 was about 68 million tons, whereas the emissions from the nine examples in FY 2020 from extraction through to manufacture and disposal will be 4.75 million tons in total, which is only a fraction of the former figure.

It is planned to increase the examples of c-LCA in the future, such as those of materials that help to reduce the weight of automobiles, including the next generation automobiles (engineering plastics, etc.), materials for secondary batteries (materials for positive and negative electrodes, electrolytic fluids, separators) and materials for flat panel displays, etc. Although the manufacture of chemical products consumes a lot of energy, it is necessary to promote a deeper understanding that the use of chemical products helps to reduce CO_2 emission by considering aspects of analysis using c-LCA.

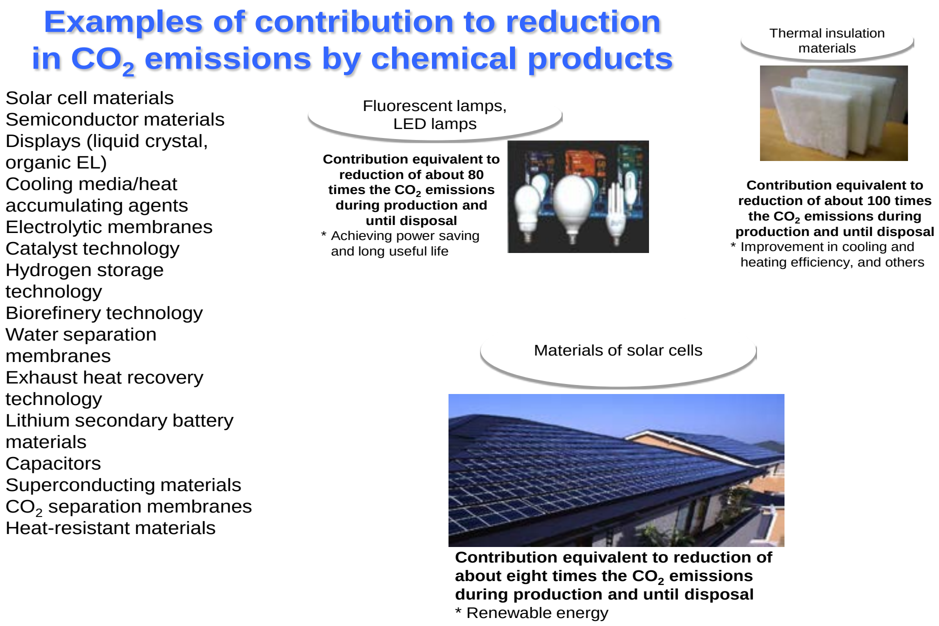


Fig. 31. Examples of chemical products helping to reduce CO_2 emission

6.2 Promoting avoided CO_2 emissions internationally

The chemical industry has been helping to reduce carbon emissions in developing countries as well as various countries overseas by adopting and supplying chemical processes and energy-saving technologies of the world's highest level. When a new factory was to be built overseas, the principles of so-called responsible care have been implemented, in which the environment, safety and health are voluntarily protected, and improved reliability expressed by society and communications have been promoted in all the processes from product development through manufacture and use to disposal.

As seen in the materials used in seawater desalination plants in this report, namely, RO membranes, the technical transfer of Japan's chemical products and technologies also helps to reduce emissions overseas, and this will become increasingly important in the future. It is important that c-LCA concerning the international contribution of chemical products and technologies will also be implemented, reflecting the nature of the market as it expands around the world.

[Examples of how the transfer of low carbon technologies overseas has helped to reduce CO_2 emission]

Manufacturing technology: Provision of chemical processes and energy-conservation technologies of the world's highest standard

- Manufacturing technology for polycarbonate using CO_2 as a raw material in the Middle Eastern and Asian countries
- State-of-the-art manufacturing equipment for telephthalic acid in India and China
- Manufacturing technology for acrylamide that uses biotechnology in South Korea
- Caustic soda manufacturing equipment that reduces power during electrolysis through the use of an ion exchange membrane in the Middle East, Asia, Europe and America
- Ethylene plant in Singapore that is a world leader in energy efficiency

Unprocessed materials/products: In the stage of use, CO_2 can be substantially reduced as compared with conventional unprocessed materials and methods

- Seawater desalination technology using reverse osmosis membranes
- Drainage treatment system that incorporates multistage aeration tanks
- Control devices for the DC motors for air conditioners

Treatment for making three alternatives to Freon harmless: Under development with the support of NEDO

- Reduction in the emissions of three alternatives to Freon through the installation of exhaust gas combustion equipment
- Achieved substantial reduction in PFCs to 70% in the basic unit of discharge relative to that in the reference year, and in SF_6 to 95%.
- We will promote reduction in the emission of greenhouse gases through the transfer of technologies overseas in cooperation with the national government by using production technologies owned by businesses and exhaust gas combustion equipment to reduce the emissions of alternatives to Freon.

6.3 Development of innovative technologies

The chemical industry uses fossil resources as raw materials and fuels, and technical development plays an important role in achieving a low carbon society. To overcome the problems in and the barriers to development, it is necessary to promote development by sharing the roadmap and cooperating with the national government. It is also desirable that the degree to which development contributes to the environmental aspects be demonstrated through the implementation of quantitative analysis, such as that carried out in c-LCA.

Major intermediate and long-term technical development in the chemical industry is shown below.

(1) Innovative process development

- Development of innovative processes that reduce wastes and byproducts
- Development of innovative processes for naphtha decomposition
- Development of distillation and separation technology using precision separation membranes
- Development of high-efficiency separation and refining processes by using high-performance porous materials

(2) Development of processes for manufacturing chemical products that do not use fossil resources

- Development of processes for manufacturing chemical products that use CO_2 as a raw material
- Development of processes for manufacturing propylene from cellulose-based biomass ethanol

(3) Development of high-performance materials that help reduce GHG emissions in terms of LCA

- High-efficiency thermal insulation materials for use in construction
- Solar cell materials (high-efficiency compound semiconductors, organic-based solar cells, etc.)
- Next-generation automobiles
  - # Materials for weight reduction (engineering plastics, etc.)
  - # Parts for secondary batteries (materials for positive and negative electrodes, electrolytic fluids, separators, etc.)
  - # Parts for fuel cells
- Next-generation high-efficiency lighting (high efficiency LEDs, organic ELs, etc.)
- Materials for flat panel displays (organic ELs, etc.)
- Materials for high-efficiency heat pumps (cooling media, heat-accumulating agents)
- CO_2 separation membranes, hydrogen manufacturing and storage technologies, etc.

(4) Development of chemical technologies and the creation of new parts, materials and products according to the Cool Earth Innovative Energy Technology Plan

7. Review committee for the c-LCA Report

7.1 Overview of the review committee

The c-LCA Report review committee meeting was held from 3:00 pm to 5:00 pm on June 2, 2011 (in Room 805 on the 8th floor of the Tekko Kaikan). The following four people attended the meeting: chairperson Masahiko Hirao (Professor, Department of Chemical System Engineering, School of Engineering, the University of Tokyo), committee member Atsushi Inaba (Professor, Department of Environment and Energy Chemistry, Kogakuin University), committee member Yasunari Matsuno (Associate Professor, Department of Materials Engineering, School of Engineering, the University of Tokyo), and committee member Hiroki Hondo (Associate Professor, Research Institute of Environment and Information Sciences, Yokohama National University). A summary of the results of the investigation had been presented to the committee members beforehand. One member of the committee, Yuki Hondo, was unable to attend the meeting, and he submitted his opinions in advance by means of an interview.

Note that the members of the review committee were not concerned with obtaining the data used in the investigation, and did not directly verify the completeness, representativeness, accuracy, etc. of the data in the report. Therefore, they are not responsible for anything beyond the scope for which they presented their opinions about the temporal range of the data's effectiveness, and so forth.

The members of the review committee highlighted the following matters, which are itemized in the overview of review results.

7.2 Expert opinions on the c-LCA Report

(1) Overview of the review results

1) Calculation of avoided CO_2 emission

The calculation of the avoided CO_2 emission (170 million tons) in seawater desalination only is accounted for the data of overseas while others are of Japan. It should be dealt with separately from the cumulative value of the avoided CO_2 emission of the nine examples (281.97 million tons).

2) Degree to which chemical products contribute to the avoided CO_2 emission

In this report, the object of comparison should basically be a state in which no chemical products to be analyzed are available. However, with regard to the avoided CO_2 emission, some examples include the contribution of chemical products as well as the effect of reduction of all products to be analyzed. For instance, the examples of automobiles and aircraft in the case of carbon fiber indicate that the avoided CO_2 emission is achieved through weight reduction (change in unprocessed materials). In contrast, avoided CO_2 emission in the examples of wind turbine power generation is achieved through the equipment as a whole, instead of the unprocessed materials only, and the two are different in nature.

3) Suitability of the product for comparison

The object of comparison in the example of thermal insulation materials for housing is specified as housing that does not have thermal insulation. However, there are some thermal insulation materials that are not chemical products. Therefore, there is some deviation from reality, and there are some doubts concerning the suitability of the object of comparison.

4) Description on treatment for disposal

In the section on the evaluation of plastics, incineration is not considered at the stage of disposal. Therefore, the portion equivalent to the CO_2 emission when the plastics are incinerated is calculated as less than the actual value. This may create the suspicion that the results are biased in favor of chemical products. There should be a clear description of how the CO_2 emission at the stage of disposal are evaluated.

5) Approaches to the reduction of CO_2 emission

When viewed from the perspective of how the BAU (business-as-usual) should be regarded, this report assumes, when making a comparison to evaluate the effect of reduction in CO_2 emission, that no chemical products are available. This is a unique method compared with those employed in investigations that are normally carried out.

6) Status of the years 2005 and 2020

What are the statuses of the year 2005, which is the reference year, and the year 2020, which is considered in the analysis? Six years have elapsed since 2005, and the world situation has already changed. When conducting the evaluation based on 2005, the values in 2005 should be used for electric power utilities as well, instead of using the value planned for 2020.

7) Communications with the parties concerned

As a general rule, an investigation that involves making comparisons and publishing the results should invite the parties that are the subject of comparison and analysis to participate in the review. In the future, it is desirable that communications be established with the parties concerned about the contents of the report.

8) On the significance of this report

It would be a good opportunity for having the various stakeholders focus on how the contribution of unprocessed materials (contribution of chemical products) should be considered from now on.

9) Individual matters

[1] Solar power generation

It is better to add the following statement: “consideration has been given to prevent the evaluation of the reduction in CO_2 emission from becoming excessive” in place of: “the difference between the cumulative amount of introduction of solar power generation systems in 2005 and that in 2020 was calculated, and …… dividing the difference by 15 years.”

[2] Wind turbine power generation

Since the examples of analysis are those obtained in Japan, it is considered that large wind turbine power generators of the 3-MW class as well as small wind turbine power generators contribute to the reduction in CO_2 emission. Since there is likely to be variation in the amount of power the turbines generate, it would be better to carry out sensitivity analysis. There was also an opinion that the analysis in this investigation includes future predictions where there are major fluctuations, so it would be difficult to analyze individual parameters.

[3] Automobiles

It is thought that the weight of a conventional model, the data of fuel economy, and lifetime mileage that are used for comparison are worse than the current values. Examination of temporal effectiveness is required to check whether the cited data is older than that obtained for the reference year.

[4] Piping

Piping made of polyvinyl chloride and piping made of ductile cast iron are used according to each of the different applications, and it might not be possible to say that they are always interchangeable. It is better to describe the situation of use according to each application.

[5] Source

It is desirable that full details of the sources be given instead of simplified sources, such as the website of the Ministry of Economy, Trade and Industry. The details should include the year of issuance, and the representativeness of data and the range of temporal effectiveness, as far as possible.

[6] Others

- It is helpful for readers to incorporate the Executive Summary in the material for review into this report (either in the conclusion or at the beginning). Also, it is better to specify in the report sentences corresponding to the "contents of contribution" that are given in the Executive Summary.
- Regarding the items in section 6.3, “Development of innovative technologies,” a more elaborate description should be given and the items should have richer content.

(2) Examination of and response to the result of the review

1) Calculation of the avoided CO_2 emission (geographical conditions)

As a member of the committee pointed out, since the object of calculation is overseas in seawater desalination only, it has been determined that the calculation should be dealt with separately from other examples in Japan. At the same time, the result will not be added to the avoided CO_2 emission in Japan.

2) Degree of contribution of chemical products in the avoided CO_2 emission

As a member of the committee pointed out, the emission avoided CO2 emission includes that of chemical products as well as that of other materials and products related to parts. However, there is currently no technique for distributing chemical products and non-chemical products quantitatively. Therefore, the avoided CO_2 emission has not been distributed according to each constituent product, and a clear description has been given in the text to that effect.

3) Suitability of a product for comparison

We searched the literature intently in our search for a suitable product for comparison necessary for calculating the effect of thermal insulation materials. However, we found no appropriate object of comparison except housing without thermal insulation, and we adopted it. Two problems remain to be addressed hereafter to improve the method of calculation. They are: [1] Understanding the differences in the number of houses and the thermal insulation properties of housing with no thermal insulation, the former criteria for energy saving, the new criteria for energy saving, and the next-generation criteria for energy saving, and [2] comparisons with thermal insulation materials made of other unprocessed materials, such as rock wool or glass wool.

4) Description of the treatment for disposal

The evaluation of CO_2 emission in the stage of disposal in each example has been described as shown below, and at the same time it has been added to the text.

[1] Solar cells

- Aluminum frames and terminal boxes (including cables for wiring) that have been separated from removed and collected solar cell modules should be recycled by suppliers of recycling services.
- It has been specified that other modules should be treated as industrial waste. Materials that can be recycled after intermediate treatment of such waste should be recycled, and those that cannot be recycled should be disposed of in landfill.

[2] Materials for wind turbine power generation

Since there is no previous record of disposal, it has been excluded from the calculation.

[3] Automotive materials

It has been specified in this model that automotive resins and carbon fibers will be recycled as CFRP by crushing them and adding them at the time of injection molding.

[4] Materials for aircraft

Since there is no previous record of disposal, it has been excluded from the calculation.

[5] LEDs

It has been specified that LEDs will be discharged as noncombustible waste and will be disposed of by landfill after intermediate treatment.

[6] Thermal insulation materials (expanded polystyrene foam)

It has been specified that it will be incinerated.

[7] Hall effect devices/ICs

Air conditioners for domestic use will be disposed according to the Electric Appliance Recycling Law. Since the methods of disposal of air conditioners vary, they have been excluded from the calculation in this report.

[8] Piping materials

It has been specified that they will be disposed of by landfill after intermediate treatment.

[9] Seawater desalination

It has been specified that RO membrane elements will be disposed of by landfill as industrial waste.

5) Approach to the reduction of CO_2 emission

The products under analysis are based on products and technologies available in 2010. Products that are expected to come into widespread use in 2020 as the result of technical progress are not used as objects of comparison. Also products that have to be used when no chemical products are available are used as objects of comparison. The avoided CO_2 emission is calculated based on the forgoing by multiplying it by the expected volumes manufactured in 2020.

The points mentioned above are already described in this report.

6) Status of the years 2005 and 2020

Although FY 2005 has significance as the reference year in the mid-term target, no comparison has been made with FY 2005 in this report. Also, the reason for using FY 2020 as the year under analysis has been included in section 3.1, “Background and purpose.”

7) Communications with the parties concerned

It is planned that, after completion of this c-LCA report, it will be used to expand communication through dialog with the various stakeholders, such as the industrial, academic and administrative sectors, as well as with members of the public.

8) Individual matters

[1] Solar power generation

The reason for calculating the difference between the cumulative degree to which solar power generation systems were introduced in 2005 and will be introduced in 2020, and the reason for dividing the difference by 15 years and using the result as the degree to which the systems have been introduced to "[2] Effect of introduction throughout Japan"

[2] Wind turbine power generation

Since it is expected that further efforts will be made to promote the introduction of renewable energy, it is planned that the degree to which small wind turbine power generators will contribute to the reduction in CO_2 emission will also be reviewed when the plans for installing the generators have been clarified in the future.

[3] Automobiles

The years from which the data that forms the basis of the analysis comes and the fiscal years during which the sources were issued have been added.

[4] Piping

Notation has been added stating that, considering the fact that substitution is not possible with piping made of polyvinyl chloride in some applications, estimated forecasts of demand for polyvinyl chloride piping have been conservative.

[5] Sources

Extensive information concerning the fiscal years, the names of reports, URLs, and so forth have been given.

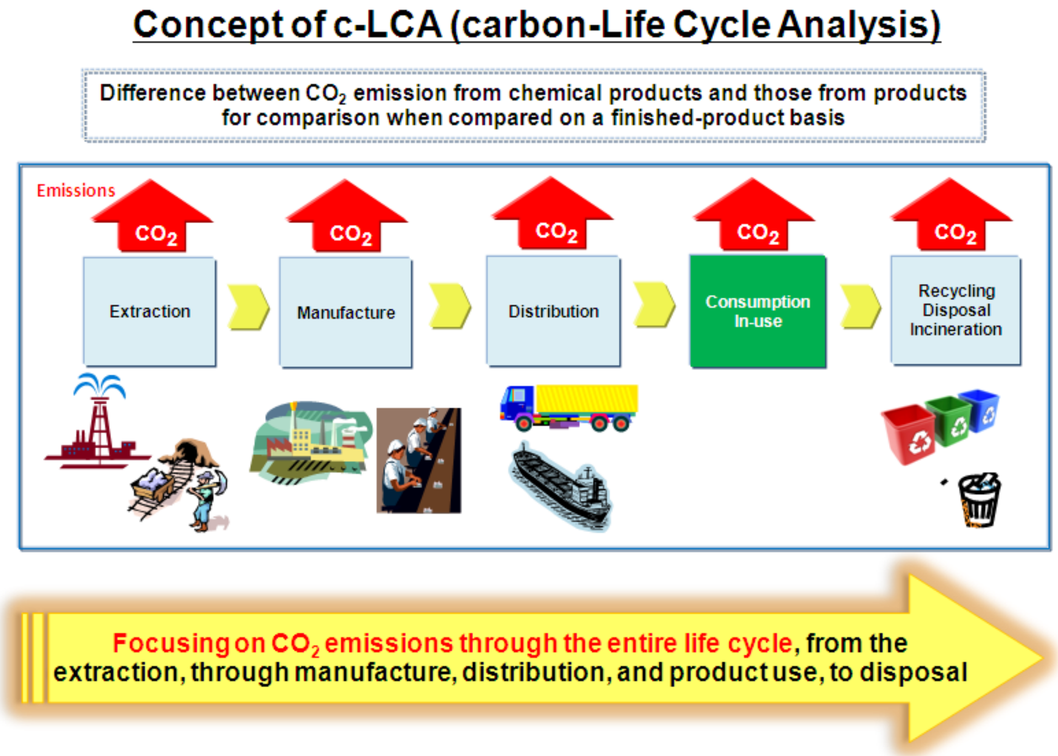
[6] Other matters

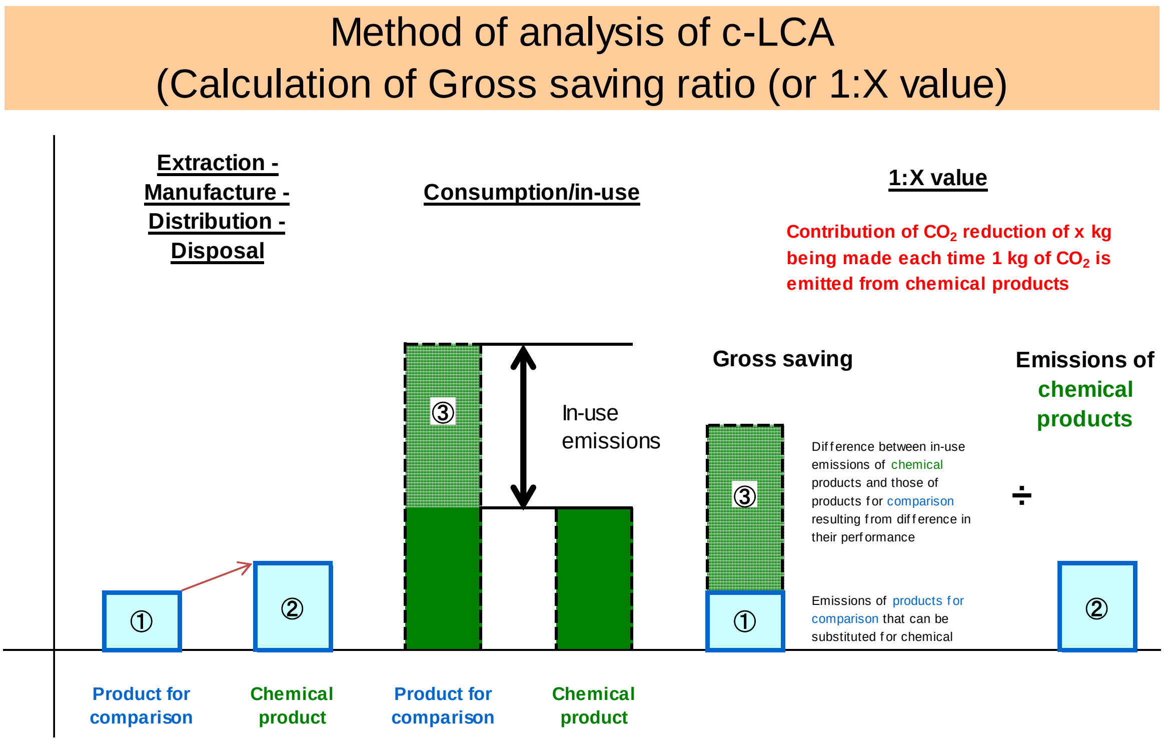
- Following the matter indicated, the contents of the Executive Summary have been incorporated into the report.
- The column for section 6.3, “Development of innovative technologies” has been revised to include more specific development items.

8. Appendix: c-LCA Fact Sheet

Gross saving (or 1:X) ratio

In addition to the avoided CO_2 emission that has been shown in the text, another means of analyzing c-LCA has been adopted, namely, the gross saving (or 1:X value) ratio. This value has been added to the appendix.

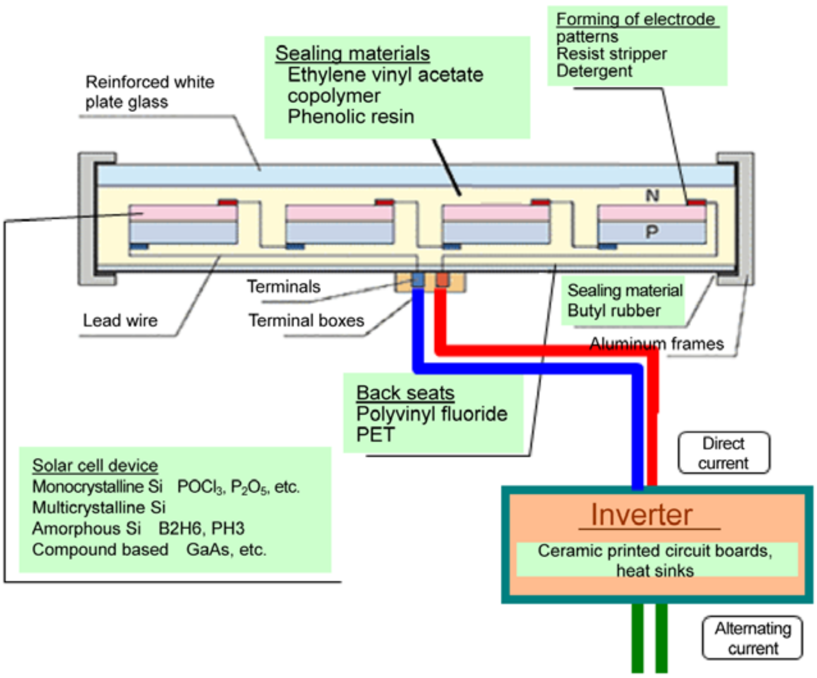




This index is calculated by adding the difference in emissions during use resulting from the difference in performance between chemical products and products for comparison to the emissions of the products for comparison from their extraction through manufacture to disposal when no chemical products are available, and by dividing the difference by the emissions of the chemical products themselves.

Calculating the index involves calculating the ratio of the degree to which X kg contributes to reducing CO_2 emission each time that 1 kg of CO_2 is emitted by chemical products in the stages of extraction through to manufacture and disposal.

■ Materials for solar power generation

No.	Item	Contents
1	Product overview	What is a solar cell? A solar cell is a device that directly converts energy from the sun into electrical energy using the principle of a semiconductor. Since power can be generated in any place and since the scale of the system is arbitrary, it is possible to install the system in domestic houses. It is expected that the use of solar cells will continue to expand as a form of renewable energy. Configuration of a solar cell   Examples of chemical products used in solar cells • Multicrystalline Si, SiH_4 gas, Si wafer • Sealing materials for solar cells (ethylene vinyl acetate copolymer, phenolic resin) • Back seat for solar cells (polyvinyl fluoride, PET) • Various chemicals (detergent, resist stripper) • Diethylzinc, BCl_3, CVD materials • Ceramic printed circuit board for inverters, heat sink

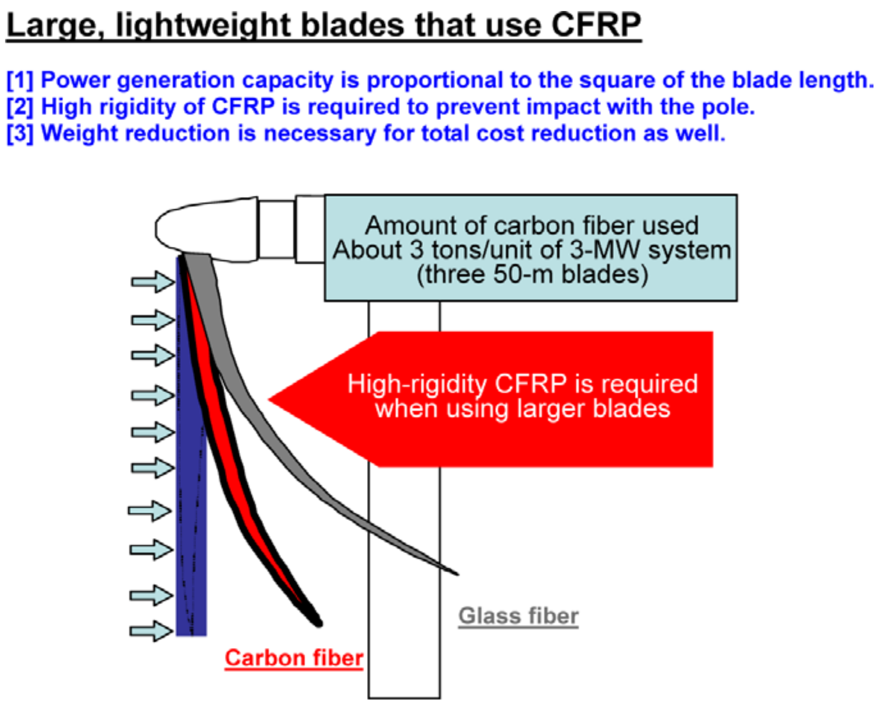
2	Scope of analysis using c-LCA	
2-1	Product system to be analyzed	Analysis target • Product: Multicrystalline Si solar cell, useful life: 20 years, output: 4-kW class Comparison target • Product: Electric power utilities (power source mix)
2-2	Functions	• The object is supply of a certain amount of electric energy.
2-3	Functional unit and reference flow	Functional unit • Amount of power generated: 902 kWh (amount of power generated per kW of output) at Tokyo Reference flow • Solar power generation: Portion equivalent to 1 kWh (annual power generation of 902 kWh per kW) • Electric power utilities (power source mix)
2-4	System scope	Processes to be analyzed • In the case of solar power generation, all emissions in processes from the extraction through to manufacture, use, maintenance (replacement of parts), disposal of power generation systems using multicrystalline silicon solar cells. • In the case of electric power utilities, all emissions from power generation systems based on the power source mix and processes from the fuel production, fuel transportation, the extraction through to manufacture, use, maintenance (replacement of parts), disposal of waste (predicted value for the year 2020)
2-5	Preconditions for c-LCA	• The portion of the increase from chemical products includes that for the manufacture of multicrystalline Si, sealing materials and back covers. • Effect of avoided CO_2 emission is calculated based on a comparison with the amount of power generated in electric power utilities (2-2).
3	Result of analysis using c-LCA	
3-1		

	Analysis target	Comparison target
	Multicrystalline solar cell	Electric power utilities
1) CO_2 emission in manufacturing stage (kg-CO_2/kW)		
• Transportation of SiO_2 and manufacture of Si	57.95	
• Multicrystalline Si agglomerate	445.91	
• Manufacture of multicrystalline Si ingot	26.72	
• Manufacture of wafer	145.02	
• Sealing materials	42.9	
• Back seat	16.5	
Total for manufacturing stage	**735**	–
2) Effect of reduction in CO_2 emission of solar power generation		
• CO_2 emission coefficient during power generation (kg-CO_2/kWh)	0.047	0.33
• Annual amount of power generation per kW of solar power generated (Tokyo) (kWh)	902	902
• CO_2 emission relative to annual power generated per kW of solar power generated (kg-CO_2/kW/year)	42.39	297.66
• Reduction in CO_2 emission relative to annual amount of power generated per kW of solar power generation (kg-CO_2/kW/year)	255.27	
3) Lifetime effect of reduction in CO_2 emission of solar power generation (kg-CO_2/kW/20 years)	**5,105**	
■1:X	**7**	

3-2	Reduction in CO_2 emission per unit of solar power generation introduced	Preconditions • The portion of the increase was calculated from CO_2 emission during the manufacture of chemical products to be used in solar power generation (crystalline Si wafer, back seat, sealing materials). The factor of CO_2 emission from solar power generation factor that was included in this portion was extracted. • Avoided CO_2 emission was obtained from the reduction in CO_2 emission relative to electric power utilities (power source mix) resulting from the power generated by a solar power system produced in 2020 to the end of its life (calculated as a value per kWh). Result of analysis • Reduction relative to electric power utilities: 5,105 kg-CO_2/kW/20 years
3-3	Gross saving ratio	• Analysis relative to electric power utilities: [1:X] 7
4	Analysis based on the scenario for introducing solar power generation	
4-1	Target for introducing solar power generation set by the national government, etc.	• As the effect of reduction in CO_2 emission in 2020 varies greatly depending on the degree to which solar power generation is introduced, the calculations were made conservatively. The difference between the cumulative degree to which solar power generation systems were introduced in 2005 (1.4 million kW) and that in 2020 (27.8 million kW) was calculated, and the average annual increment was determined by dividing the difference by 15 years.
4-2	Degree to which solar power is introduced, based on the scenario	• It is assumed that the output from solar power generation systems introduced by 2020 will be 1.76 million kW.
4-3	Reduction in CO_2 emission based on the scenario	Method of calculation • (3-2) × (4-2) Result of calculation • 8,980,000 t-CO_2

■ Materials for wind turbine power generation

<table>
<tr><th>No.</th><th>Item</th><th>Contents</th></tr>
<tr><td>1</td><td>Product overview</td><td>What is wind turbine power generation?
Wind turbine power generation has been used as a form of natural energy since olden times, and it is expected to continue to be used as a clean energy to combat global warming. The utilization rate for wind turbine power generation is high as it can be produced at day and at night. Thanks to its high conversion efficiency, it is also a low-cost source of power.
To increase the amount of power generated in this way, it is necessary to use larger blades. However, the rigidity of the blades must also be increased to prevent the blades from colliding with the tower. The modulus of elasticity of carbon fiber is more than three times that of the conventional glass fiber, and for this reason, carbon fiber is being increasingly used for the girders of large blades. The use of offshore wind turbine power generation, where the wind conditions are favorable, is expected to increase greatly, with large windmills of 3 MW or more being used. As the use of larger windmills, such as 5 MW and 10 MW, becomes more common, carbon fiber is becoming increasingly important.

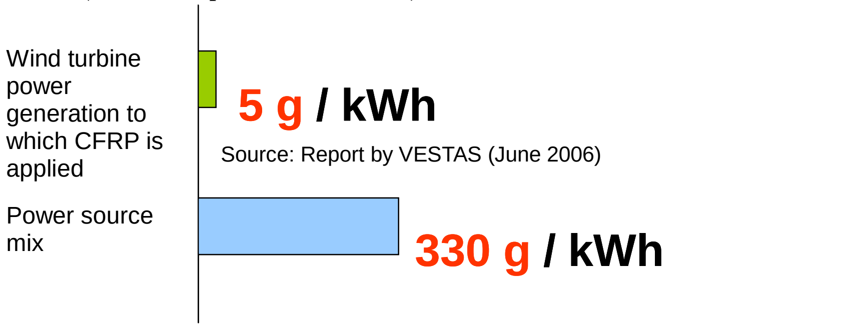
Image of a windmill [60]


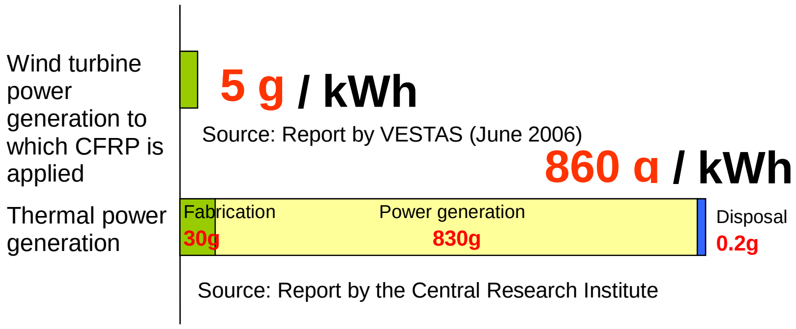
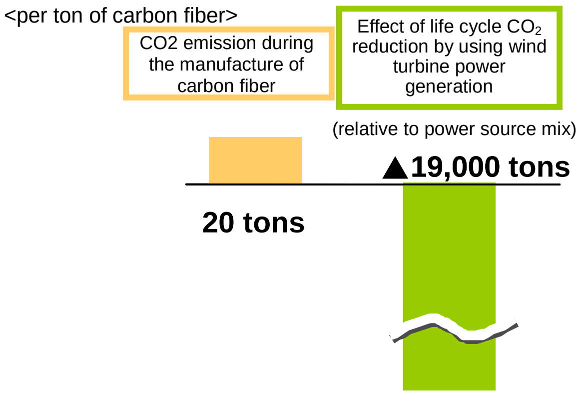
Chemical products used in wind turbine power generation
• Carbon fiber
• Epoxy resin</td></tr>
</table>

[60] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

<table>
<tr><td>2</td><td colspan="5">Scope of analysis using c-LCA</td></tr>
<tr><td>2-1</td><td>Product system to be analyzed</td><td colspan="4">Analysis target
• Product: Wind turbine power generator, useful life: 20 years, output: rated, 3 MW (effective: 1 MW)
(Turbines that require rigid blades with girders made from carbon fiber)
Comparison target
• Product: Electric power utilities (power source mix)</td></tr>
<tr><td>2-2</td><td>Functions</td><td colspan="4">• The analysis target using c-LCA should be functions for supplying a certain amount of electric energy.</td></tr>
<tr><td>2-3</td><td>Functional unit and reference flow</td><td colspan="4">Functional unit
• Wind turbine power generator: 1 unit of the 3-MW class
• Amount of power generated: 175,200 MWh (lifetime amount of power generated per unit of wind turbine power generator)
• Power source mix: portion equivalent to the above amount of power generated</td></tr>
<tr><td>2-4</td><td>System scope</td><td colspan="4">Processes to be analyzed
• In the case of wind turbine power generation, all emissions in processes from the extraction through to manufacture, use, maintenance (replacement of parts) and disposal of the power generation systems. Disposal was excluded from the calculation because there is no record of disposing of these systems. Also, since the CO_2 emission from the extraction to manufacture of the carbon fiber are not taken into account, they have been added as an increment during equipment manufacture. However, emissions associated with materials substituted by carbon fiber (e.g. glass fiber, etc.) have not been excluded.
• In the case of electric power utilities, all emissions from the power generation systems based on the power source mix and in processes from fuel production, fuel transportation, the extraction through to manufacture, use, maintenance (replacement of parts) and waste disposal (predicted value for the year 2020)</td></tr>
<tr><td>2-5</td><td>Preconditions for c-LCA</td><td colspan="4">• The portion of the increase from chemical products includes that for the manufacture of carbon fiber.
• Avoided CO_2 emission is calculated based on a comparison between wind turbine power generation and power source mix assuming that the same amount of power is generated (those that have the same functions as described in 2-2).</td></tr>
<tr><td>3</td><td>Result of analysis using c-LCA</td><td>Processes to be analyzed</td><td>Wind turbine power generation 3-MW class</td><td>Power source mix Case A</td><td>Thermal power generation Case B</td></tr>
<tr><td rowspan="3">3-1</td><td rowspan="3">CO_2 emission related to the entire life cycle</td><td>• CO_2 emission coefficient during power generation (kg-CO_2/kWh)</td><td>0.005</td><td>0.33</td><td>0.86</td></tr>
<tr><td>• Annual amount of power generated per unit of wind turbine power generator (MWh)</td><td>8,760</td><td>–</td><td>–</td></tr>
<tr><td>• CO_2 emission relative to annual amount of power generated per unit of wind turbine power generator (1,000 t-CO_2/unit/year)</td><td>0.04</td><td>2.9</td><td>7.5</td></tr>
</table>

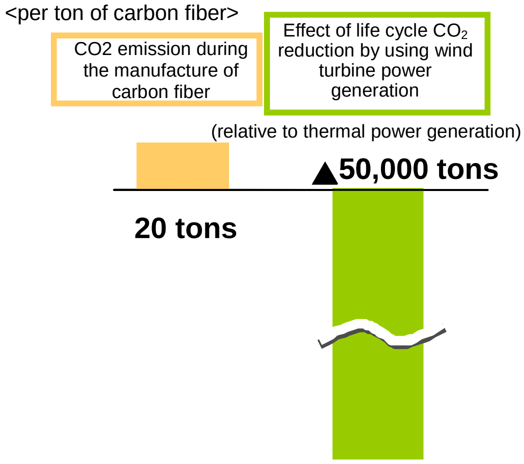
<table>
<tr><td></td><td></td><td>• CO_2 emission relative to lifetime amount of power generated per unit of wind turbine power generator (useful life of windmill: 20 years) (1,000 t-CO_2/unit/year)</td><td>0.8</td><td>58</td><td>150</td></tr>
<tr><td></td><td></td><td colspan="4">Life cycle CO_2 emission[61]
(per kWh)

Case A (relative to power source mix)


Case B (relative to thermal power generation)

</td></tr>
<tr><td>3-2</td><td>Reduction in CO_2 emission per unit of wind power generation introduced</td><td colspan="4">Case A (relative to power source mix)
• Effect of reduction in CO_2 emission: 56,940 t/unit▪20 years
• Amount of CF[62] used: 3 t/unit
⇒ Effect of reduction in CO_2 emission per ton of CF = 19,000 t[63]


• Gross saving ratio
Evaluation relative to thermal power generation: [1:X] 960</td></tr>
</table>

61 Source: Website of the Japan Carbon Fiber Manufacturers Association (http://www.carbonfiber.gr.jp/)
62 CF: Carbon Fiber
63 Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

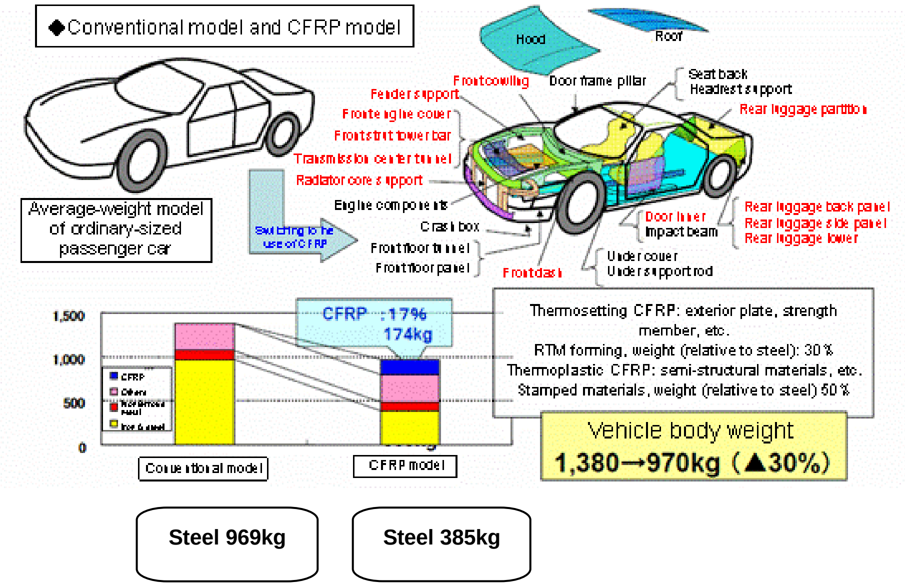
		Case B (relative thermal power generation) • Effect of reduction in CO_2 emission: 150,000 t/unit▪20 years • Amount of CF used: 3 t/unit ⇒ Effect of reduction in CO_2 emission per ton of CF = 50,000 t  • Gross saving ratio Evaluation relative to thermal power generation: [1:X] 2,500
4	Analysis based on the scenario for introducing wind turbine power generation	
4-1	Prediction for introducing wind turbine power generation	Case 1: Calculation on a trial basis based on the national government's prediction for introducing wind turbine power generation • Annual output from windmills introduced in Japan in 2020: 450 MW • Amount of CF used in windmill applications in Japan in 2020: 450 t Case 2: Value based on calculation on a trial basis by the CF Association • Annual output from windmills introduced in Japan in 2020 predicted by the CF Association: 1,500 MW • Amount of CF used in windmill applications in 2020 (Amount to be produced by three PAN-based CF manufacturers in Japan and used in windmills globally) Globally: 30,000 t In Japan: 1,500 t (5% of the amount to be produced globally)
4-2	Scenario for introducing wind turbine power generation and degree to which it is introduced based on the scenario	Case 1: Calculation on a trial basis based on the national government's prediction for introducing wind turbine power generation[64] • Annual output from windmills introduced in Japan in 2020: 450 MW • Amount of CF used: 3 t/unit • Wind turbine power generator: 3-MW class/unit Number of windmills using CFRP in Japan in 2020: 150 units Case 2: Value based on calculation on a trial basis by the CF Association • The amount used in 2020 is estimated to be 15 times that used in 2007.[65] • Amount of CF used: 3 t/unit • Wind turbine power generator: 3-MW class/unit • Number of windmills using CFRP in 2020 Globally: 10,000 units In Japan: 500 units

[64] Website of the Ministry of Economy, Trade and Industry
http://www.meti.go.jp/committee/summary/0004629/framework.html

[65] Source: Website of the Japan PVC Pipe and Fittings Association, http://www.ppfa.gr.jp

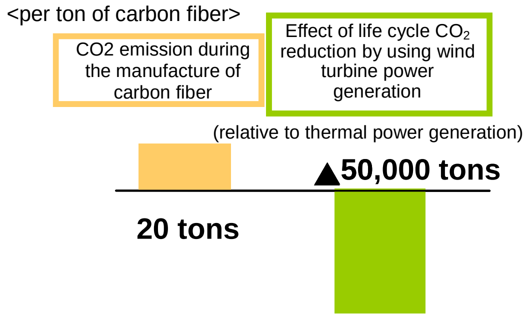
4-3	Reduction in CO_2 emission based on the scenario	Case 1A: Calculation on a trial basis based on the national government's prediction for introducing wind turbine power generation/relative to power source mix • Effect of reduction in CO_2 emission per ton of CF is 19,000 t/20 years • Reduction in CO_2 emission in Japan in 2020: 8,540,000 t-CO_2/20 years Case 2B: Value based on calculation on a trial basis by the CF Association/relative to thermal power generation • Effect of reduction in CO_2 emission per ton of CF is 50,000 t/20 years • Reduction in CO_2 emission in 2020 Globally: 1,500,000,000 t-CO_2/20 years In Japan: 75,000,000 t-CO_2/20 years
4-4	Points to be noted on the above reduction in CO_2 emission	Case 1: Calculation on a trial basis based on the national government's prediction for introducing wind turbine power generation • CO_2 emission during the manufacture of CF In Japan: 9,000 t-CO_2 Case 2: Value based on calculation on a trial basis by the Carbon Fiber Association • CO_2 emission during the manufacture of CF Globally: 600,000 t-CO_2 In Japan: 30,000 t-CO_2
4-5	Other matters worth specially noting	• None

■ Automotive materials (carbon fiber)

No.	Item	Contents
1	Product overview	What is automotive carbon fiber? Carbon fiber has a range of applications as an automotive material. The use of carbon fiber enables weight reduction while maintaining strength and safety. Reducing the weight of automobiles leads directly to improved fuel economy, thereby helping to reduce CO_2 emission in the transportation sector. This report evaluates the reduction in CO_2 emission through the reduction in fuel consumption by comparing conventional automobiles with those that use carbon fiber.[66] Conventional and CFRP models of ordinary-sized automobiles[67]  Chemical products used • Carbon fiber • Epoxy resin
2	Scope of analysis using c-LCA	
2-1	Product system to be analyzed	Analysis target • CFRP model of ordinary-sized automobiles Automobiles using CFRP: Use of 17%CFRP, weight reduction of 30% (compared with conventional automobiles) Vehicle weight: 970 (kg) ··· A reduction of 30% (410 kg) in overall weight through the use of 17% (174 kg) CFRP Lifetime mileage: 94,000 km (average useful life: 10 years) Fuel economy: 12.40 km/l[68] Comparison target • Conventional model of ordinary-sized automobile Vehicle weight: 1,380 kg Lifetime mileage: 94,000 km[69] (average useful life: 10 years) Fuel economy: 9.83 km/l

[66] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
[67] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
[68] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
[69] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

2-2	Functions	• The analysis target using c-LCA should achieve the lifetime mileage and functions of an automobile of average weight and ordinary size.		
2-3	Functional unit and reference flow	Functional unit • CFRP model of ordinary-sized automobile: 1 unit (average useful life: 10 years) • Conventional model of ordinary-sized automobile: 1 unit (average useful life: 10 years) • Lifetime mileage: 94,000 km (average useful life: 10 years)		
2-4	System scope	Processes to be analyzed • Processes related to the extraction through to manufacture • Processes related to assembly of the product • Processes related to use of the product • Processes related to disposal of the product Processes to be omitted • Processes related to transportation of the product		
2-5	Preconditions for c-LCA	• In using c-LCA to analyze the products during use, it is assumed that they have the functions described in (2-2) and that no functions are added or omitted for the purpose of comparison.		
3	Result of analysis using c-LCA	Processes to be analyzed	CFRP automobile	Conventional automobile
3-1	CO_2 emission related to the extraction through to material production	CO_2 emission related to the extraction through to material production (t-CO_2/unit)	5.1	3.9
3-2	CO_2 emission related to assembly	CO_2 emission related to assembly (t-CO_2/unit) • Assuming that reduction is based on the weight ratio	0.8	1.2
3-3	CO_2 emission related to use	Processes related to the combustion of gasoline during use		
		Vehicle weight (kg/unit)	970	1,380
		Fuel economy (km/l▪gasoline)	12.40	9.83
		Amount of gasoline (l/unit) for lifetime mileage of 94,000 (km)	7,580	9,560
		Basic unit for gasoline combustion (kg-CO_2/l)	2.72	2.72
		CO_2 emission related to use (t-CO_2/unit▪10 years)	20.6	26.0

<table>
<tr><td>3-4</td><td>CO_2 emission related to disposal</td><td><u>CO_2 emission related to disposal (t-CO_2/unit)</u>
• 90% or more of ferrous and non-ferrous materials will be recycled
• 100% of CFRP parts will be recycled as milled CF (for use in other applications)</td><td><u>0.3</u></td><td><u>0.3</u></td></tr>
<tr><td>3-5</td><td>CO_2 emission related to the entire life cycle</td><td><u>CO_2 emission related to the entire life cycle (t-CO_2/unit▪10 years) (total of 3-1 through 3-4)</u></td><td><u>26.8</u></td><td><u>31.4</u></td></tr>
<tr><td>3-6</td><td>Reduction in CO_2 emission per unit of materials introduced</td><td colspan="3">• Effect of reduction in CO_2 emission: 5 t/unit▪10 years
• Amount of CF used: 0.1 t/unit
⇒ Effect of reduction in CO_2 emission per ton of CF = 50 t[70]


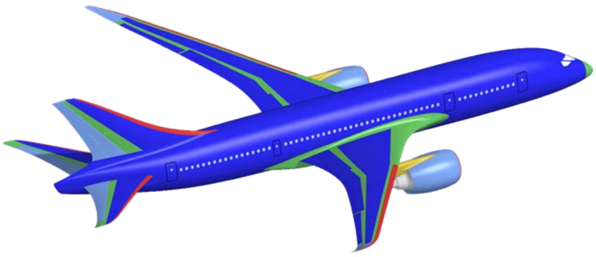
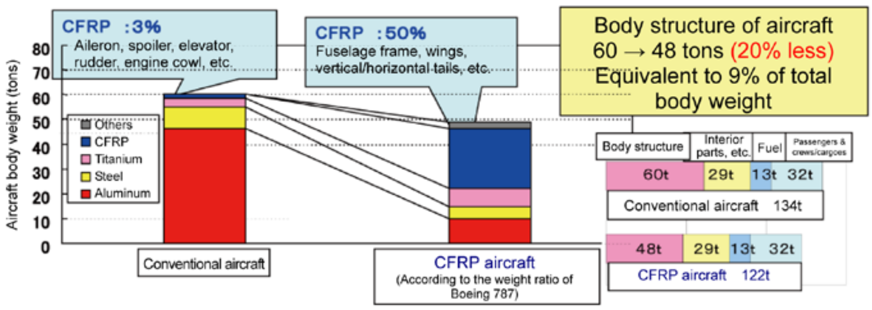
• Gross saving ratio
Evaluation relative to conventional automobiles made of steel: [1:X] 2.5</td></tr>
<tr><td>4</td><td colspan="4">Sensitivity analysis</td></tr>
<tr><td>4-1</td><td>Prediction for introducing the materials</td><td colspan="3">• Amount of CF used for automotive use in 2020[71]
(Amount to be produced by three PAN-based CF manufacturers in Japan and used in automobiles globally)
Globally: 30,000 t
In Japan: 1,500 t (5% of the amount to be produced globally)</td></tr>
<tr><td>4-2</td><td>Scenario for introducing the materials, and degree to which the materials are introduced, based on the scenario</td><td colspan="3">• The amount to be used in 2020 is estimated to be 15 times that in 2007.
• Amount of CF used: 0.1 t/unit
• Number of automobiles using CFRP in 2020
Globally: 300,000 units
In Japan: 15,000 units</td></tr>
<tr><td>4-3</td><td>Reduction in CO_2 emission based on the scenario</td><td colspan="3">• Effect of reduction in CO_2 emission: 5 t/unit▪10 years
• Reduction in CO_2 emission in 2020
Globally: 1,500,000 t-CO_2/10 years
In Japan: 75,000 t-CO_2/10 years</td></tr>
</table>

70 Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
71 Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

4-4	Points to be noted on the reduction in CO_2 emission	• CO_2 emission from the extraction through to assembly and disposal (calculated from 6.2 t-CO_2/unit) Globally: 1,860,000 tons t-CO_2 In Japan: 93,000 t-CO_2
4-5	Other matters worth specially noting	• Calculation of automotive resins and carbon fibers is made on the basis of reuse as CFRP by crushing them and adding them during injection molding.

■ Materials for aircraft (carbon fiber)

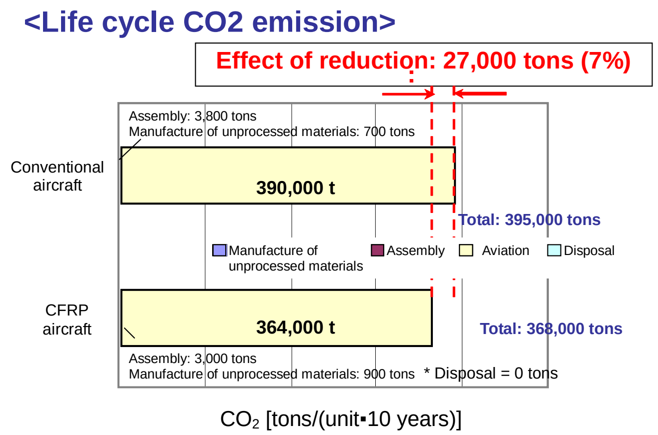
<table>
<tr><th>No.</th><th>Item</th><th>Contents</th></tr>
<tr><td>1</td><td>Product overview</td><td>What is carbon fiber for aircraft use?
Carbon fiber has a range of applications as a material for use in aircraft. The use of carbon fiber enables weight reduction while maintaining strength and safety. As with automobiles, reducing the weight of aircraft directly leads to improved fuel economy, thereby helping to reduce CO_2 emission in the transportation sector. This report evaluates the reduction in CO_2 emission through the reduction in fuel consumption by comparing conventional aircraft with aircraft that use carbon fiber[72]

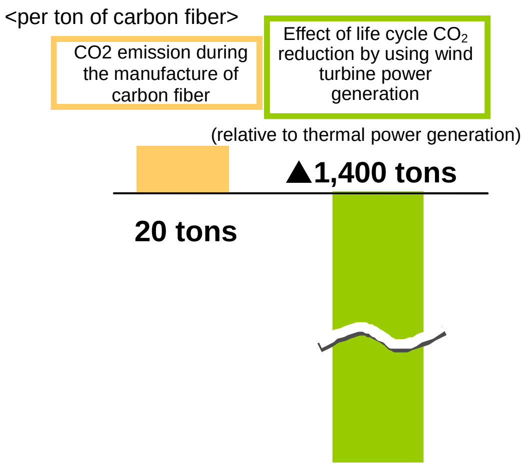
Aircraft specifications

Using Boeing 767 having a model body structure of the same material composition as Boing 787


Chemical products used
• Carbon fiber
• Epoxy resin</td></tr>
<tr><td>2</td><td colspan="2">Scope of analysis using c-LCA</td></tr>
<tr><td>2-1</td><td>Product system to be analyzed</td><td>Analysis target[73]
• Aircraft body: The body of a Boeing 767 having the same material composition as that of a Boeing 787, with 20% weight reduction achieved by using CFRP in 50% of the body structure[74].
The total weight reduction is 9%.
Aviation: Domestic route (Haneda - Chitose: 500 miles).
Distance flown during lifetime: 2,000 flights/year, 10 years
Comparison target
• Product: Boeing 767, seats: 280, CFRP used in 3% of body structure.
Aviation: Domestic route (Haneda - Chitose: 500 miles).</td></tr>
</table>

72 Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp
73 Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp
74 The weight of aircraft is composed of those of fuselage structure, interior parts, etc., fuel, humans/cargoes.

		Distance flown during lifetime: 2,000 flights/year, 10 years		
2-2	Functions	• The analysis target using c-LCA should be able to provide transportation services for the same period as those of a Boeing 767.		
2-3	Functional unit and reference flow	Functional unit • Model aircraft having material composition that is equivalent to that of Boeing 787: 1 unit (average useful life: 10 years) • Boeing 767: 1 unit (average useful life: 10 years)		
2-4	System scope	Processes to be analyzed • Processes related to the excavation of raw materials through to product manufacture • Processes related to assembly of the product • Processes related to use of the product • Processes related to disposal of the product (however, disposal is not counted because no data are available) Processes to be omitted • Processes related to transportation of the product • Processes related to the manufacture of capital goods		
2-5	Preconditions for c-LCA	• In using c-LCA to analyze the products during use, it is assumed that they have the functions described in (2-2) and that no functions are added or omitted for the purpose of comparison.		
3	Result of analysis using c-LCA	Processes to be analyzed	CFRP aircraft	Conventional aircraft
3-1	CO_2 emission related to the extraction through to material production and manufacture	**CO_2 emission related to the extraction through to material production (kt-CO_2/unit)**	**0.9**	**0.7**
3-2	CO_2 emission related to assembly	**CO_2 emission related to assembly (kt-CO_2/unit)** • Assuming that reduction is based on the weight ratio	**3.0**	**3.8**
3-3	CO_2 emission related to use	Processes related to the consumption of fuel during use		
		Aircraft body weight (t/unit)	48	60
		Fuel economy (km/kl)	110	103
		Amount of jet fuel consumed during lifetime (kl/unit)	145,500	155,300
		Basic unit for jet combustion (kg-CO_2/l)	2.5	2.5
		CO_2 emission related to use (kt-CO_2/unit▪10 years)	**364**	**390**
3-4	CO_2 emission related to disposal	**CO_2 emission related to disposal (kt-CO_2/unit)**	**No data**	**No data**

<table>
<tr><td rowspan="2">3-5</td><td rowspan="2">CO_2 emission related to the entire life cycle [75]</td><td><u>CO_2 emission related to the entire life cycle (kt-CO_2/unit▪10 years) (total of 3-1 through 3-3)</u></td><td><u>368</u></td><td><u>395</u></td></tr>
<tr><td colspan="3">


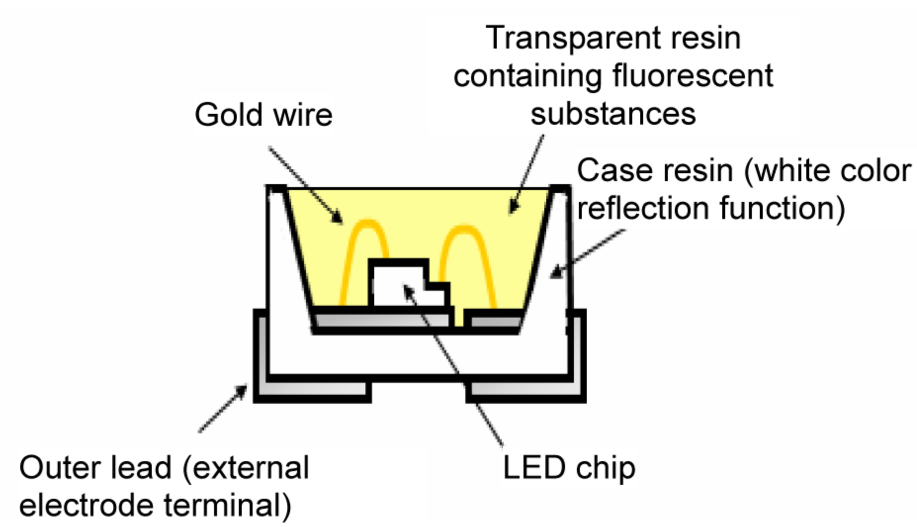
</td></tr>
<tr><td>3-6</td><td>Reduction in CO_2 emission per unit of materials introduced [76]</td><td colspan="3">
• Effect of reduction in CO_2 emission: 27,000 t/unit▪10 years
• Amount of CF used: 20 t/unit
⇒ Effect of reduction in CO_2 emission per ton of CF = 1,400 t


• Gross saving ratio
Evaluation relative to conventional aircraft made of aluminum: [1:X] 70
</td></tr>
<tr><td>4</td><td colspan="4">Analysis based on the scenario for introducing the materials</td></tr>
<tr><td>4-1</td><td>Prediction for introducing the materials</td><td colspan="3">
• Amount of CF used for aircraft use in 2020 [77]
(Amount to be produced by three PAN-based CF manufacturers in Japan and used in aircraft globally)
Globally: 18,000 t
In Japan: 900 t (5% of the amount to be produced globally)
</td></tr>
</table>

[75] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
[76] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/
[77] Source: Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

4-2	Scenario for introducing the materials and degree to which the materials are introduced based on the scenario	• The amount to be used in 2020 is estimated to be 5 times the track record in 2007. • Amount of CF used: 20 t/unit • Number of aircrafts using CFRP in 2020 Global: 900 units Japan: 45 units
4-3	Reduction in CO_2 emission based on the scenario	• Effect of reduction in CO_2 emission: 27,000 t/unit･10 years • Reduction in CO_2 emission in 2020 Globally: 24.3 million t-CO_2/10 years In Japan: 1.22 million t-CO_2/10 years
4-4	Points to be noted on the above reduction in CO_2 emission	• CO_2 emission from the extraction to assembly (calculated from 3.9 t-CO_2/unit) Globally: 3.51 million t-CO_2 In Japan: 0.176 million t-CO_2
4-5	Other matters worth specially noting	• None

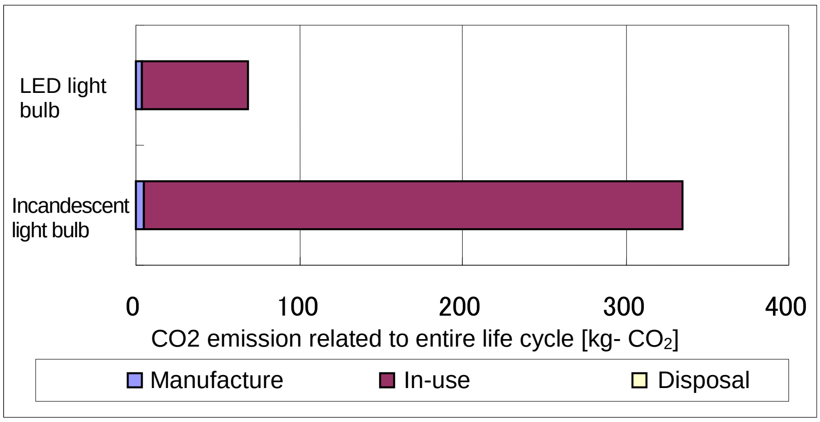
■LED related materials

No.	Item	Contents
1	Product overview	What is an LED? An LED (light emitting diode) emits light when an electric current is made to flow through it, and it is made from compound semiconductors. Unlike incandescent lamps and fluorescent lamps that until now have been the most widespread, LEDs emit light without being heated, so the use of LEDs is expected to increase as a highly efficient form of lighting. Configuration of an LED   Examples of chemical products used in LEDs • LED package • LED chip • LED printed circuit board (GaAs, GaP, GaN, SiC, and sapphire) • Organic metals for use in MO-CVD • LED sealing materials (epoxy, silicone) • LED resin packages (reflector resins: polyamide based, silicone, liquid crystal polymer) • LED ceramic packages • Fluorescent substances • High heat dissipation printed circuit boards • High reflectance film, paint for improving luminance, etc.

2	Scope of analysis using c-LCA			
2-1	Product system to be analyzed	Analysis target • Product: LED lamp, useful life[78]: 25,000 hours/unit, power consumption: 8 W/unit Comparison target • Product: Incandescent light bulb, useful life[78]: 1,000 hours/unit, power consumption: 40 W/unit		
2-2	Functions	• The analysis target using c-LCA should have the same level of brightness over the same period.		
2-3	Functional unit and reference flow	Functional unit • Useful life: 25,000 hours Reference flow • LED lamp: 1 unit • Incandescent light bulb: 25 units		
2-4	System scope	Processes to be analyzed • Processes related to the excavation of raw materials and transportation through to product manufacture • Processes related to use of the product • Processes related to disposal of the product		
2-5	Preconditions for c-LCA	• It is assumed that the products to be analyzed using c-LCA have the functions described in (2-2).		
3	Result of analysis using c-LCA	Processes to be analyzed	LED lamp	Incandescent light bulb
3-1	CO_2 emission related to the extraction through to manufacture	[1] During extraction - manufacture		
		Power consumption during manufacture (kWh/unit)	9.9	0.612
		Number of products manufactured (units)	1	25
		CO_2 emission coefficient during power generation[79] (kg-CO_2/kWh)	0.33	0.33
		CO_2 emission relative to extraction - manufacture (kg-CO_2)	**3.27**	**5**
3-2	CO_2 emission related to use	[2] In-use		
		In-use power consumption (25,000 hours) (kWh)	200	1,000
		CO_2 emission coefficient during power generation[79] (kg-CO_2/kWh)	0.33	0.33
		CO_2 emission related to use (kg-CO_2)	**66**	**330**
3-3	CO_2 emission related to disposal	[3] Landfill		
		Number of pieces disposed of by landfill (units)	1	25
		Basic unit for landfill (kg-CO_2/unit)	0.002	0.009
		CO_2 emission related to disposal (kg-CO_2)	**0.002**	**0.225**

78 Source: OSRAM "Life Cycle Analysis of Illuminants: A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps" (December 2009)

79 Electric power emission factor (power receiving end) in FY 2020: Target value of the Federation of Electric Power Companies of Japan

3-4	CO_2 emission related to the entire life cycle	**<u>CO_2 emission related to the entire life cycle (kg-CO_2/25,000 hours) (total of [1] through [3])</u>**	**<u>69.272</u>**	**<u>335.225</u>**
				
3-5	Reduction in CO_2 emission per unit of LED lamps introduced	Preconditions • The reduction in CO_2 emission has been obtained by comparing the emissions from an LED lamp produced in a certain year due to its continued operation until its end of life with those of a substitute incandescent light bulb. • The evaluation assumes that the life is 25,000 hours. Result of analysis • 266 kg-CO_2/unit		
3-6	Gross saving ratio	• 82 [1:X]		
4	Analysis based on the scenario for introducing the LED lamps			
4-1	Target for introducing the LED lamps set by the national government, etc.	Basic Energy Plan • To increase high-efficiency lighting (LEDs, etc.) to 100% in 2020 in terms of flow, and to 100% in 2030 in terms of stock		
4-2	Degree to which the LED lamps are introduced, based on the scenario[80]	• The annual sales forecast should be used as the scenario for introducing the LED lamps. • Annual sales of LED lamps in Japan: 28,000,000 (2020)		
4-3	Reduction in CO_2 emission based on the scenario	Method of calculation • (3-5) × (4-2) Amount of CO_2 emission reduction based on the scenario for introducing the LED lamps • 7,450,000 t-CO_2		
4-4	Points to be noted on the above reduction in CO_2 emission	• None		
4-5	Other matters worth specially noting	• None		

80 Source: Fuji Chimera Research Institute "General Investigation of LED Related Markets (first volume)" (2010)

■ Thermal insulation materials for housing

No.	Item	Contents
1	Product overview	Role of thermal insulation materials in housing[81] The energy used in cooling and heating (especially heating) a house is one of the major forms of energy use in the home. To make optimum use of the energy consumed by cooling and heating, it is necessary to improve the thermal insulation and air tightness of the residence. In this way, it is possible to minimize the heat that flows through the walls, ceiling, roof, floor, windows, entrances and other apertures in the residence if there is a temperature difference, even if the temperature indoors is comfortable. If the interior of a room is wrapped in thermal insulation, the transfer of heat can be minimized.   Examples of chemical products used as thermal insulation materials for housing • Extruded polystyrene foam • Expanded Polystyrene foam • Hard urethane foam, urethane resin, propylene oxide • Highly expanded polystyrene foam • Phenol foam, PVC sash, PVC resin • Heat-shielding paint, heat-shielding sheets, heat-shielding film, high thermal insulation curtains, nonwoven fabric • Alumina fiber What is expanded polystyrene foam?[82] Expanded polystyrene foam is called “EPS”, which is an acronym for expanded polystyrene. It is typical of the foamed plastic-based thermal insulation materials developed in Germany. The method for manufacturing expanded polystyrene foam is that, after raw material beads consisting of polystyrene resin and hydrocarbon-based foaming agents have been subjected to preparatory foaming, they are foamed to about 30 to 80 times their volume by pouring them into molds and heating them. In this way, various shapes of products can be manufactured, according to the shape of the mold.

[81] Source: "Energy-saving Housing web Let's Promote Energy-saving Housing" in the website of the Japan Federation of Housing Organizations
http://eco.judanren.or.jp/learning/103.html

[82] Source: "Overview of EPS Construction Materials" in the website of the Japan Expanded Polystyrene Association, EPS Construction Materials Promotion Department
http://www.epskenzai.gr.jp/what/what01.html

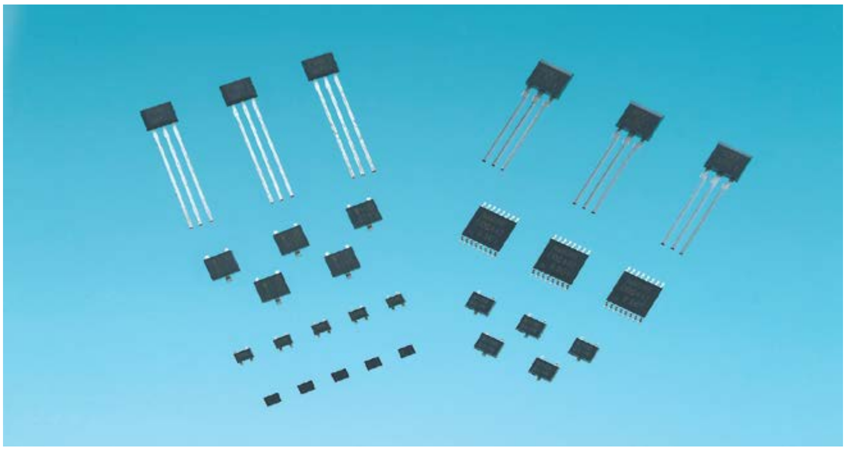
2	Scope of analysis using c-LCA							
2-1	Product system to be analyzed	Analysis target[83] • Product: Freestanding house (single materials and thermal insulation), useful life: 30 years • Product: Apartment (single materials and thermal insulation), useful life: 60 years Comparison target • Product: Freestanding house (no thermal insulation materials), useful life: 30 years • Product: Apartment (no thermal insulation materials), useful life: 60 years						
2-2	Functions	• Analysis target using c-LCA: New houses expected to be constructed in 2020						
2-3	Functional unit and reference flow	Functional unit • Useful life: 30 years (freestanding house), 60 years (apartment) Reference flow • Freestanding houses: 367,000 residences (common to analysis target and comparison target) • Apartments: 633,000 residences (common to analysis target and comparison target) • Total: 1,000,000 residences						
2-4	System scope	Processes to be analyzed • Processes related to the extraction, manufacture and disposal of thermal insulation materials • Processes related to the use of housing Processes to be omitted • Processes related to the manufacture and disposal of housing • Energy consumption used during use other than that for air conditioning (e.g. gas cooking stove, etc.)						
2-5	Preconditions for c-LCA	• In using c-LCA to analyze the products during use, it is assumed that they have the functions described in (2-2).						
3	Result of analysis using c-LCA (freestanding houses)	Processes to be analyzed	Sapporo	Morioka	Sendai	Tokyo	Kagoshima	Average
3-1	CO_2 emission in manufacturing stage (kg-CO_2/residence)		2,295	1,687	1,520	1,520	1,520	1,709
3-2	CO_2 emission during use (kg-CO_2/residence)		-49,443	-40,564	-28,613	-16,642	-12,140	-29,480
3-3	CO_2 emission in the stage of disposal (kg-CO_2/residence)		2,412	1,773	1,598	1,598	1,598	1,796
3-4	**Avoided CO_2 emission (kg-CO_2/residence)**		**-44,736**	**-37,104**	**-25,495**	**-15,122**	**-9,022**	**-25,975**
4	Result of analysis using c-LCA (freestanding houses)	Processes to be analyzed	Sapporo	Morioka	Sendai	Tokyo	Kagoshima	Average
4-1	CO_2 emission in manufacturing stage (kg-CO_2/residence)		1,145	855	714	687	687	818

[83] Source: Japan Expanded Polystyrene Recycling Association "EPS Product Environmental Load (LCI) Analysis and Investigation Report" (April 2007)

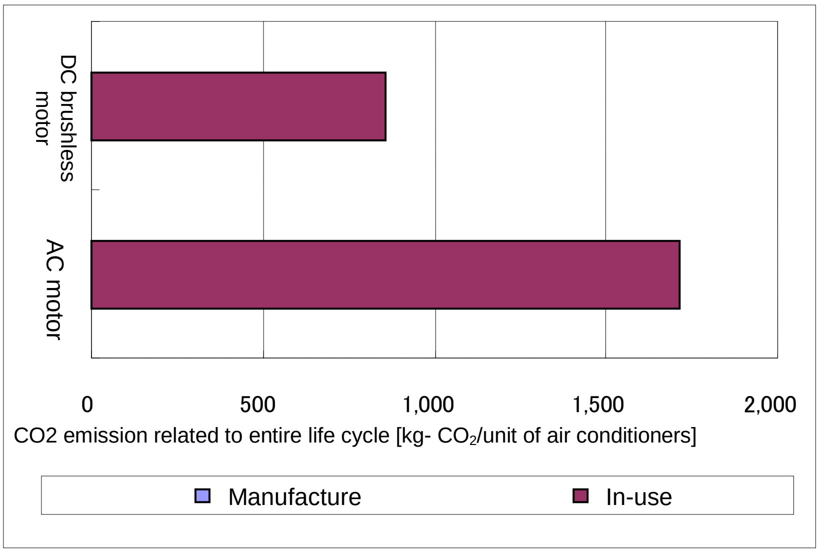
4-2	CO_2 emission during use (kg-CO_2/residence)	-173,405	-146,661	-100,622	-65,361	-45,861	-106,382
4-3	CO_2 emission in the stage of disposal (kg-CO_2/residence)	1,204	899	751	722	722	859
4-4	**Avoided CO_2 emission (kg-CO_2/residence)**	**-171,056**	**-144,908**	**-99,157**	**-63,952**	**-44,452**	**-104,705**

5	Analysis based on the scenario for introducing the materials	
5-1	Target for introducing the materials set by the national government, etc.	Basic Energy Plan • To achieve ZEB･ZEH (Net Zero-Emission Building/House) by 2030 on an average of newly built residences
5-2	Degree to which the materials are introduced, based on the scenario	Freestanding houses • Number of residences in which the materials are introduced: 367,000 residences Apartments • Number of residences in which the materials are introduced: 633,000 residences
5-3	Reduction in CO_2 emission based on the scenario	Freestanding houses • Net amount of emission reduction: **Total 9.5 million t-CO_2** • Gross saving ratio [1:X]: **7.4** Apartments • Net amount of emission reduction: **Total 66.5 million t-CO_2** • Gross saving ratio [1:X]: **62.4**
5-4	Points to be noted on the above reduction in CO_2 emission	• Since no information is available on the number of residences in which the materials are introduced in each region, the simple average for all regions multiplied by the number of residences in Japan is used. It is necessary to develop a more detailed way of thinking about the number of residences in which the materials are introduced.
5-5	Other matters worth specially noting	• None

■ Hall effect device, Hall effect IC

No.	Item	Contents
1	Product overview	What is a DC brushless motor? A DC brushless motor is a motor running on direct current that does not have a commutator. It has the advantage of superior efficiency (power conservation) compared to an AC motor (induction motor). AC motors having inferior energy efficiency were conventionally used for the fans of indoor and outdoor units, but in Japan where there are stringent regulations for energy conservation, DC brushless motors are currently used. A DC brushless motor changes its polarity by using a Hall effect IC to detect the position of the rotor. The polarity of the motive power is changed by providing feedback to the control circuit by means of a signal representing the position. Appearance of a Hall effect IC 
2	Scope of analysis using c-LCA	
2-1	Product system to be analyzed	Analysis target • Product: DC brushless motor, efficiency: 80%, useful life: 8 years Comparison target • Product: AC motor, efficiency: 40%, useful life: 8 years
2-2	Functions	• The object of analysis using c-LCA should realize functions for supplying the same motor output in the same period.
2-3	Functional unit and reference flow	Functional unit • Motor output of air conditioner outdoor unit: 70 W/unit ▪ air conditioner • Motor output of air conditioner indoor unit: 60 W/unit ▪ air conditioner • Useful life: 8 years, annual operating hours: 2,000 hours Reference flow • Since a DC brushless motor and an AC motor have the same functions, the number of DC or AC motors to be mounted on one air conditioner is the same.

2-4	System scope	Processes to be analyzed • Only the processes related to the manufacture and use of Hall effect device/IC products are to be analyzed. Processes to be omitted • Extraction/material production, transportation, manufacture, and disposal/recycling of finished air conditioner products • Processes related to the manufacture of capital goods		
2-5	Preconditions for c-LCA	・Analysis using c-LCA should involve analyzing the motors to be mounted onto individual air conditioners. ・In using c-LCA to analyze the products during use, it is assumed that they have the functions described in (2-2) and that there are no functions added or omitted for the purpose of comparison. ・It is assumed that the DC brushless motor consists of a Hall effect IC (an IC that contains a Hall effect device and an amplifier) incorporated into an AC motor. (It is assumed that the CO_2 emission during manufacture of the DC brushless motor are equal to the CO_2 emission during manufacture of the AC motor plus the CO_2 emission during manufacture of the Hall effect device and Hall effect IC.) ・Therefore, the difference in CO_2 emission between the analysis target and the comparison target related to the manufacture of the motors should be excluded from the calculations.		
3	Result of analysis using c-LCA	Processes to be analyzed	DC brushless motor	AC motor
3-1	CO_2 emission related to extraction/ material production	Out of scope	–	–
3-2	CO_2 emission related to manufacture	[1] Manufacture		
		CO_2 emission related to the manufacture of Hall effect devices (kg-CO_2/unit)	<<1	–
		CO_2 emission related to the manufacture of Hall effect ICs (kg-CO_2/unit)	<<1	–
		CO_2 emission related to manufacture (kg-CO_2/unit)	**<<1**	–
3-3	CO_2 emission related to use	[2] In-use		
		Annual electrical energy consumption (2,000 hours) (kWh/year/unit)	325	650
		Number of years of operation	8	8
		Total electrical energy in the number of years of operation (kWh/unit)	2,600	5,200
		CO_2 emission coefficient during power generation (kg-CO_2/kWh)	0.33	0.33
		CO_2 emission related to use (kg-CO_2/unit)	**858**	**1,716**
3-4	CO_2 emission related to disposal	Out of scope	–	–

3-5	CO_2 emission related to the entire life cycle	**CO_2 emission related to the entire life cycle (kg-CO_2/unit) (total of [1] and [2])**	**858**	**1,716**
				
3-6	Reduction in CO_2 emission per unit of hall effect devices introduced	Preconditions • The reduction in CO_2 emission should be determined by substituting an air conditioner containing a DC brushless motor that is produced in a certain year, which will be put into continuous operation in the future until the end of its life cycle, with an air conditioner containing an AC motor. • The evaluation should assume that the operating lifetime is 16,000 hours. Result of analysiss • 858 kg-CO_2/unit ▪ air conditioner		
3-7	Gross saving ratio	• About 6,000 [1:X]		
4	Analysis based on the scenario for introducing hall effect devices			
4-1	Prediction for introducing the devices[84]	• Number of air conditioners in demand globally in 2020: 100,832,000 units		
4-2	Degree to which the devices are introduced based on the scenario	• By predicting that the number of units to be sold in Japan in 2020 remains flat starting in 2010, and the demand forecast value according to the region in 2010 should be used. • Annual number of air conditioners sold in Japan: 7,460,000 (2020)		
4-3	Reduction in CO_2 emission based on the scenario	Method of calculation • (3-6) × (4-2) Amount of CO_2 emission reduction based on the scenario for introducing the products • 6,400,000 t-CO_2/year		
4-4	Points to be noted on the above reduction in CO_2 emission	• None		

[84] Source: Fuji Chimera Research Institute "General Investigation of Worldwide Electronics Markets in 2009 - Market Analysis and Trend in Future of AV, Home Electric Appliances, Information/Telecommunications Equipment, Electronic Units" (2009)

4-5	Other matters worth specially noting	• None

■ Piping materials (polyvinyl chloride piping)

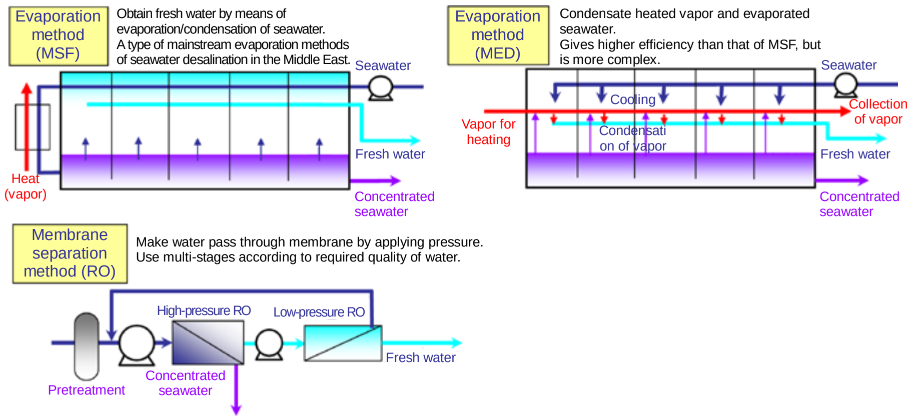
No.	Item	Contents
1	Product overview	Polymer piping materials include polyvinyl chloride piping, polyethylene piping and polybutene piping. Together with metal piping materials, they are widely used as water supply piping (for water distribution, water supply piping and drainage) and gas piping (low pressure conduit). Of the polymer piping materials, polyvinyl chloride piping is low in carbon content, consuming fewer fossil resources, and involving low CO_2 emission throughout its life cycle.  Chemical products used in piping materials • Polyvinyl chloride (EDC, monomer, polymer) • High-density polyethylene • Polybutene
2	Scope of analysis using c-LCA	
2-1	Product system to be analyzed	Analysis target: Polyvinyl chloride piping Comparison target Ductile cast iron piping
2-2	Functions	• The analysis target using c-LCA should have the functions of a pipe that conveys the same fluid in the same period.
2-3	Functional unit and reference flow	Functional unit • Polyvinyl chloride piping: 1 kg (equivalent to 14.9 cm of 150 mm water piping) • Assumed useful life of polyvinyl chloride piping: 50 years Reference flow • Polyvinyl chloride piping and ductile cast iron piping of the same diameter should be deemed to have the same performance in conveying fluid. • Corrections should be made based on any difference in useful life.

2-4	System scope	Processes to be analyzed • Processes related to raw materials/material production (excavation of resources - manufacture of unprocessed materials) • Processes related to product manufacture (processing into piping) • Processes related to disposal (landfill) Processes to be omitted • Processes related to transportation of products • Processes related to use of products • Processes related to manufacture of capital goods		
2-5	Preconditions for c-LCA	• Based on the weight ratio per meter of water piping 150 mm in diameter, the coefficient for weight correction of ductile cast iron piping is specified as 3.55 times. • Based on the difference in assumed useful life, the coefficient for correction in useful life for ductile cast iron piping is specified as 0.90. • After correcting for the unit weight having the same diameter/extension as well for the assumed useful life, the life cycle CO_2 emission of 1 kg of polyvinyl chloride piping are compared with the life cycle CO_2 emission of 3.95 kg of ductile cast iron piping.		
3	Result of analysis using c-LCA	Processes to be analyzed	Polyvinyl chloride piping	Ductile cast iron piping
3-1	CO_2 emission related to raw materials/material production	(1)Processes related to procurement of materials (excavation of raw materials - manufacture of unprocessed materials)		
		Unit weight (kg)	1	3.95
		Basic unit up to procurement of raw materials (kg-CO_2/kg)	1.4	0.146
		CO_2 emission related to procurement of raw materials (kg-CO_2/kg)	1.4	0.577
3-2	CO_2 emission related to production of products	(2)Processes related to production of products (processing)		
		Unit weight (kg)	1	3.95
		Basic unit for processing (kg-CO_2/kg)	0.1	1.925
		CO_2 emission related to production (kg-CO_2/kg)	0.1	7.60
3-3	CO_2 emission related to use of products	Out of scope	–	–
3-4	CO_2 emission related to disposal	(3)Processes related to disposal of products (landfill)		
		Unit weight (kg)	1	3.95
		Basic unit for landfill (kg-CO_2/kg)	0.018	0.018
		CO_2 emission related to disposal (kg-CO_2/kg)	0.018	0.071
3-5	CO_2 emission related to the entire life cycle	**CO_2 emission related to the entire life cycle (kg-CO_2/kg) (total of [1] through [3])**	**1.5**	**8.2**
3-6	Reduction in CO_2 emission per unit of piping materials introduced	Preconditions • CO_2 emission through the entire life cycle should be obtained by substituting 1 kg of polyvinyl chloride piping that has been produced for ductile cast iron piping. Result of analysis • 6.7 kg-CO_2/kg		

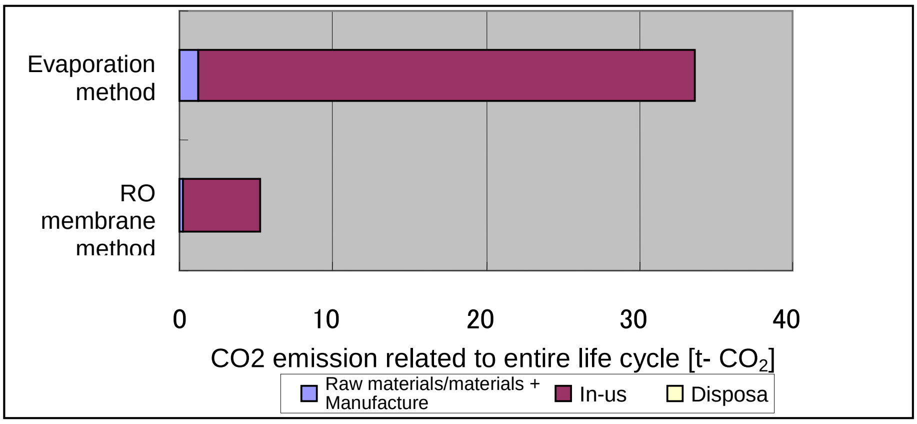
3-7	Gross saving ratio	• 4.5 [1:X]
4	Analysis based on using the scenario for introducing the piping materials	
4-1	Prediction for introducing the materials	• Amount of polyvinyl chloride piping/joints produced in 2020: 493,092 t
4-2	Degree to which the materials are introduced based on the scenario	• It is assumed that the amount of production in Japan in 2020 will be the same as that in FY 2005.
4-3	Reduction in CO_2 emission based on scenario for introducing the piping materials	Method of calculation • (3-6) × (4-1) Reduction in CO_2 emission based on the scenario for introducing the piping materials • 3,300,000 t-CO_2/year
4-4	Points to be noted on the above reduction in CO_2 emission	• In recent years, the demand for piping materials has tended to decline against a background of decreasing domestic population and stagnant housing construction starts. It is necessary to monitor the trend closely.
4-5	Other matters worth specially noting	• None

■ Materials for seawater desalination plants (RO membranes)

<table>
<tr><th>No.</th><th>Item</th><th>Contents</th></tr>
<tr><td>1</td><td>Product overview</td><td>What are RO membranes?
RO membranes (reverse osmosis membranes) are semi-permeable membranes for water treatment that have the function of blocking salts and other impurities at the molecular level, allowing fresh water to permeate.
The phenomenon in which solvents transfer from diluted solution to thick solution via a semi-permeable membrane is called permeation, and the force that initiates such transfer is called osmotic pressure. When pressure greater than osmotic pressure is applied to a thick solution, a phenomenon occurs in which the solvent transfers back to diluted solution, which is called reverse osmosis.
By utilizing this principle, it is possible to apply a pressure to a solution containing substances to be removed, such as salts, and obtain fresh, clean water. This principle is used in water treatment technology.

Application to seawater desalination plants
In the present seawater desalination plants, the technique most widely used is evaporation, in which fresh water is obtained from vaporized seawater or heated steam. However, the amount of energy that this technique uses is regarded as a problem that should be addressed. Desalination using RO membranes is now attracting attention as it requires less energy, producing fresh water from seawater by applying pressure and utilizing the reverse osmosis action of RO membranes.
</td></tr>
<tr><td>2</td><td colspan="2">Scope of analysis using c-LCA</td></tr>
<tr><td>2-1</td><td>Product system to be analyzed</td><td>Analysis target
• Product: Seawater desalination plant using RO membranes
Comparison target
• Product: Seawater desalination plant using evaporation</td></tr>
</table>

2-2	Functions	• Manufacture of fresh water using seawater as the raw materials		
2-3	Functional unit and reference flow	Functional unit • Lifetime amount of desalination of one RO membrane element: 26,000 m^3 Reference flow • Seawater desalination plant using the RO membrane method (equivalent to one RO membrane element) • Seawater desalination plant using the evaporation method (equivalent to one RO membrane element in a seawater desalination plant using the RO membrane method)		
2-4	System scope	Processes to be analyzed • Processes related to manufacture of products (including the manufacturing processes for raw materials/materials) • Processes related to use of products (including the manufacturing processes for raw materials/materials of chemicals) • Processes related to disposal of products (RO membrane elements and their related parts only) Processes to be omitted • Processes related to transportation of products • Processes related to disposal of products (other than RO membrane elements and their related parts) • Dismantling of the plant		
2-5	Preconditions for c-LCA	• In using c-LCA to analyze the products during use, it is assumed that they have the functions described in (2-2) and that there are no functions added or omitted for the purpose of comparison.		
3	Result of analysis using c-LCA	Processes to be analyzed	RO membrane method	Evaporation method
3-1	CO_2 emission related to gathering of raw materials and material production to manufacture	RO membrane element manufacturing process	**0.01**	**–**
		Manufacturing process for raw materials/materials of RO membrane elements	**0.1**	**–**
		Process for gathering raw materials/material production other than RO membrane elements, plant construction process	**2.2**	**12.4**
3-2	CO_2 emission related to use	Energy consumption resulting from plant operation, manufacturing process for the raw materials and chemical materials	**50.5**	**323.5**
3-3	CO_2 emission related to disposal	Disposal of RO membrane elements and their related parts	**0.15**	**–**
3-4	CO_2 emission related to the entire life cycle	**CO_2 emission related to the entire life cycle (t-CO_2) (total of 3-1 through 3-3)**	**53.0**	**335.9**

		
3-5	Reduction in CO_2 emission per unit of desalination plants introduced	Preconditions • Using the unit amount of desalination plants introduced per RO membrane element, the reduction in CO_2 emission represents the effect of substituting a seawater desalination plant using RO membranes for a seawater desalination plant using evaporation by taking account of the total CO_2 emission through the life cycle of the plant. Result of analysis • A reduction in 282.9 t-CO_2/amount of desalination: 26,000 m^3 per RO membrane element (From Evaporation Method - RO Membrane Method in 3-4)
4	Analysis based on the scenario for introducing seawater desalination plants	
4-1	Target for introducing the plants set by the national government, etc.	• To support new industries in water that use the best technologies, and to enable these industries to become Japan's leading export industries in the near future, the Council on Competitiveness-Nippon is being urged to establish an overall backup system involving the national government and relevant agencies. RO membranes are being highlighted as one of the best technologies.
4-2	Degree to which the plants are introduced based on the scenario	• Fresh water supply capacity worldwide using RO membranes in seawater desalination plants to be added anew in 2016: About 8.7 million m^3/day[85] • Supply capacity from RO membranes for seawater desalination of Japanese manufacturers to be newly added in 2016: About 6.1 million m^3/day (share: 70%)[86]
4-3	Reduction in CO_2 emission based on the scenario	Although the useful life of a membrane is 5 to 7 years, calculation on a trial basis has been made assuming that it is 5 years. • Method of calculation (3-5) × (4-2) × 365 × 5 ÷ (2 - 3) • Globally 170 million t-CO_2 Reduction of CO_2 emission resulting from the RO membrane plants of Japanese manufacturers: 120 million t-CO_2
4-4	Points to be	• Although many RO membranes are manufactured in Japan, they are generally

85 Source: Figure 4.2 of the "Desalination Markets, 2010"

86 Source: Fig. 9 of the Report of the Roundtable Conference on Industrial Competitiveness: "Technology for Effective Utilization of Water Treatment and Water Resources (Approach to the World's Rapidly Expanding Water Treatment Market)" (March 18, 2008)

	noted on the above reduction in CO_2 emission	used overseas in areas susceptible to water shortages. Therefore, the reduction in CO_2 emission is much more pronounced overseas.
4-5	Other matters worth specially noting	• None

Innovations for Greenhouse Gas Reductions

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